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**(54) Title: TRANSGENIC MICE EXPRESSING HUMAN CD20**

**(57) Abstract:** The present invention generally relates to non-human transgenic animals expressing human cellular markers, including CD20 and methods for using the animals to identify agents that are effective to deplete cells bearing human CD20. The transgenic animals are also useful to test safety and efficacy of anti-CD20 therapies.

## TRANSGENIC MICE EXPRESSING HUMAN CD20

This application is being filed as a PCT International Patent Application in the name of Genentech, Inc., a U.S. national corporation and resident, (Applicant for

5    all countries except US); Andrew Chee-Yuen Chan, a U.S. citizen and resident (Applicant for US only); Qian Gong, a Chinese citizen and U.S. resident (Applicant for US only); and Flavius Martin, a Romanian citizen and U.S. resident (Applicant for US only), on 11 December 2003, designating all countries and claiming priority to United States provisional application Serial Number 60/434,115, filed December

10    16, 2002, and United States provisional application Serial Number 60/476,481, filed June 5, 2003 which are hereby incorporated by reference.

**Background of the Invention**

T and B cells both comprise cell surface proteins that can be utilized as

15    markers for differentiation and identification. One such human B cell marker is the human B lymphocyte-restricted differentiation antigen Bp35, also known as "CD20". CD20 is expressed during early pre-B cell development and remains until plasma cell differentiation. It is believed that the CD20 molecule regulates a step in the activation process that is required for cell cycle initiation and differentiation.

20    CD20 is present on both normal B cells as well as malignant B cells, whose unabated proliferation can lead to B cell lymphoma. Thus, the CD20 surface antigen has the potential of serving as a candidate for targeting of B cell lymphomas with antibodies specific to the antigen. These anti-CD20 antibodies specifically bind to the CD20 cell surface antigen of both normal and malignant B cells, leading to the

25    destruction and depletion of B cells. Chemical agents or radioactive labels having the potential to destroy the tumor can be conjugated to the anti-CD20 antibody such that the agent is specifically delivered to the neoplastic B cell.

The use of monoclonal antibodies targeting CD20 has been described (see, for example, Weiner, Semin. Oncol., 26, 43-51 (1999); Gopal and Press, J. Lab.

30    Clin. Med., 134, 445-450 (1999); White et al., Pharm. Sci. Technol. Today, 2, 95-101 (1999)). Rituxan™ is a chimeric anti-CD20 monoclonal antibody that has been used widely both as a single agent and together with chemotherapy in patients with newly diagnosed and relapsed lymphomas (Davis et al, J. Clin. Oncol., 17, 1851-1857 (1999); Solal-Celigny et al., Blood, 94, abstract 2802 (1999); Foran et al., J.

Clin. Oncol., 18, 317-324 (2000). The use of radiolabeled antibody conjugates has also been described (for example, Bexxar[TM]; Zelenetz et al., Blood, 94, abstract 2806 (1999)).

The use of antibodies targeting CD20 has also been described for other
5    conditions , especially those involving autoimmunity. For example, anti-CD20 antibody therapy has been or is being evaluated in treatment of rheumatoid arthritis, systemic lupus erythromatosis and ankylosing spondylitis. (Protheroe et al., Rheumatology 38:1150(1999)) Other autoimmune conditions have also been investigated for the treatment with anti-CD20 antibodies leading to B cell depletion
10   such as autoimmune thrombocytopenia and neutropenia, and autoimmune hemolytic anemia. (Trape et al., Haematologica 88::223 (2003); Arzo et al., Annals of Rheumatic Diseases 61:922 (2002)).

In spite of the significant roles of CD20 in human lymphoma and other disorders, animal models are lacking which express the human marker. Thus, a
15   need exists for relevant animal models for disease study and pharmaceutical drug development.


**Summary of the Invention**

The present invention generally relates to non-naturally occurring non-
20   human transgenic animals expressing human cellular markers, specifically, CD20. In one aspect, the transgenic animals provide a system to identify and test novel therapeutic agents for CD20 associated disease or conditions, such as cancer. In an embodiment, the transgenic animals are useful to test efficacy and toxicities of CD20 directed therapies.

25   The invention provides a non-naturally occurring transgenic animal whose genome comprises a nucleotide sequence encoding a heterologous CD20, preferably, human CD20. The nucleotide sequence is preferably operably linked to a human endogenous promoter whereby the human CD20 is expressed on the surface of B lymphocytes. Administration of anti-human CD20 antibodies to the presently
30   described transgenic animals results in depletion of B lymphocytes expressing human CD20. In one embodiment, the human CD20 trangenic mice are characterized by expression of human CD20 on cells at a level sufficient for anti-human CD20 antibody bound to the expressing cells to affect killing of the cells,

resulting in B cell depletion of peripheral and/or circulating B cells of at least about 75% and more preferably, 80%, 85%, 90%, 95% , 99% and even 100%.

According to a another embodiment, when the genome of the animal comprises a homologous endogenous CD20 gene , the gene is disrupted or knocked

5    out such that endogenous molecule is not expressed on cell surfaces.

The present invention further provides methods of identifying agents capable of treating B cell lymphoma where the method comprises administering an agent to a transgenic animal that expresses human CD20 on B lymphocytes and determining whether there is a reduction in the number of B lymphocytes. The invention also

10    provides methods of identifying agents capable of depleting or killing cells expressing human CD20 comprising administering an agent to transgenic animals that express human CD20 and determining whether there is a reduction in the number of such cells. Further provided are agents identified according to such methods.

15    The animals of the present invention are also useful for assessing the toxicity of anti-CD20 therapeutics by administration to the presently described transgenic animals. Treatment specificity, toxicity and efficacy can also be determined by comparison of the agent's effect with that in a wild-type animal or untreated transgenic animal.

20    A non-human transgenic animal of the present invention can further provide an indication of the safety of a particular agent for administration to a human. For example, a humanized antibody or other agent can be administered to the transgenic animal and any toxic or adverse effects as a result of the administration of the agent to the animal can be monitored or identified as an indication of the safety and

25    tolerability of the humanized antibody or agent for in vivo human use. Adverse events that may occur on a short term basis include headache, infection, fever, chills, pain, nausea, asthenia, pharyngitis, diarrhea, rhinitis, infusion reactions, and myalgia. Short term adverse events are measured in days post treatment. Long term adverse effects include cytoxicity of certain cell types, bleeding events due to

30    thrombocytopenia, release of mediators due to inflammatory and/or allergic reactions, inhibition of the immune system and/or development of an anti-therapeutic agent antibody, end organ toxicity, and increased incidence of infection or malignancy. Long term adverse events are measured in months post treatment.

Another aspect of the invention involves a method for determining efficacy of an anti-CD20 agent. Efficacy can be determined by administering a range of doses of the agent to set of trangenic animals having human CD20, determining at least one dose of the agent that results in a decrease in cells bearing human CD20.

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## Brief Description of the Figures

Figure 1 shows the expression of human CD20 in mouse B220^{+} cells derived from mice without the transgene (Tg-), heterozygous (Tg+/-) and homozygous (Tg+/+) for the transgene.

10        Figure 2 provides a schematic diagram of expression of various cell surface markers (CD43, IgM, IgD) during B cell differentiation and maturation. In the Tg+ mice, hCD20 is expressed on pre-B, immature B cells and mature B cells.

Figure 3 shows the result of screening Tg+ mice for human CD20 expression in the B cells of the bone marrow. Cells were stained with anti-human CD20

15    conjugated to FITC (BD Pharmingen). Gating the cells for presence of B220 and CD43 allows delineation into the various populations of B cells. For gating, cells were stained with anti-B220 Ab conjugated to PerCP (BD Pharmingen) and with anti-CD43 Ab conjugated to PE (fluorescence, BD Pharmingen).

Figure 4 shows the result of screening Tg+ mice for human CD20 expression

20    in the B cells of the spleen. Cells were stained with anti-human CD20 conjugated to FITC (BD Pharmingen). Gating the cells for B220 and CD21 allows delineation into the various populations of B cells. For gating, cells were stained with anti-B220 Ab conjugated to PerCP (BD Pharmingen) and with anti-CD21 Ab conjugated to PE (fluorescence, BD Pharmingen). B cells with human CD20 are found in the T1

25    zone, marginal zone and T2/Follicular zone.

Figure 5 shows the result of screening Tg+ mice for human CD20 expression in the B cells of the mesenteric lymph nodes. Cells were stained with anti-human CD20 conjugated to FITC (BD Pharmingen). Gating the cells for B220 and CD21 allows delineation into the various populations of B cells. For gating, cells were

30    stained with anti-B220 Ab conjugated to PerCP (BD Pharmingen) and with anti-CD21 Ab conjugated to PE (fluorescence, BD Pharmingen).

Figure 6 shows the result of screening Tg+ mice for human CD20 expression in the B cells of the Peyer's Patches. Cells were stained with anti-human CD20 conjugated to FITC (BD Pharmingen). Gating the cells for B220 and CD38 allows

4

delineation into the various populations of B cells. For gating, cells were stained with anti-B220 Ab conjugated to PerCP (BD Pharmingen) and with anti-CD38 Ab conjugated to PE (fluorescence, BD Pharmingen). B cells with human CD20 are mature B cells and cells in the germinal centers.

5 Figure 7 is a schematic diagram of administration of anti- human CD20 mAb into Tg$^+$ mice and analysis of presence or absence of cells having human CD20. A single dose of 1 mg of anti-human CD20 monoclonal antibody was administered at day 0. Samples were taken from various tissues at day -1, day 1, 2, 3, 4, 7, 14 and 21. Samples from different tissues such as peripheral blood spleen, lymph nodes, 10 bone marrow, and Peyer's Patches were analyzed by FACs as described previously. Serum levels of anti-CD20 monoclonal antibody were also monitored.

Figure 8 shows depletion of peripheral B cells in transgenic mice treated with anti-human CD20 mAb m2H7 (BD Pharmingen). The antibodies were administered to the transgenic mice as outlined in the schematic in Figure 7 at a dose 15 of 1 mg total. FACS analyses were done on peripheral blood, spleen, lymph node, bone marrow, and Peyer's Patches with gating as described previously.

Figure 9 shows depletion of mature peripheral lymph node B cells in transgenic mice treated with anti-human CD20 mAb m2H7. The antibodies were administered to the transgenic mice as outlined in the schematic in Figure 7 at a dose 20 of 1 mg total. FACS analyses were done on peripheral blood, spleen, lymph node, bone marrow, and Peyer's Patches with gating as described previously.

Figure 10 shows depletion of splenic T2 and follicular B cells in transgenic mice treated with anti-human CD20 mAb m2H7. The antibodies were administered to the transgenic mice as outlined in the schematic in Figure 7 at a dose of 1 mg 25 total. FACS analyses were done on peripheral blood, spleen, lymph node, bone marrow, and Peyer's Patches with gating as described previously.

Figure 11 shows depletion of re-circulating mature B cells in transgenic mice treated with anti-human CD20 mAb m2H7. The antibodies were administered to the transgenic mice as outlined in the schematic in Figure 7 at a dose of 1 mg total. 30 FACS analyses were done on peripheral blood, spleen, lymph node, bone marrow, and Peyer's Patches with gating as described previously.

Figure 12 shows depletion of mature B cells and resistance of Peyer's Patches germinal center B cells to depletion in transgenic mice treated with anti-human CD20 mAb m2H7. The antibodies were administered to the transgenic mice

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as outlined in the schematic in Figure 7 at a dose of 1 mg total. FACS analyses were done on peripheral blood, spleen, lymph node, bone marrow, and Peyer's Patches with gating as described previously.

Figure 13 shows depletion and recovery of B cells following administration
5    of anti-CD20 mAb. Antibody was administered to the mice at day 1. At day 6 post antibody treatment, B cells expressing human CD20 in the peripheral blood were not detectable. At week 6, upon clearance of the antibody, hCD20+ cells begin to be detected. By week 14, B cells appeared to have recovered to normal levels. Recovery results from precursor B cells which do not express CD20 and that then
10   subsequently develop into mature B cells with human CD20+.

Figure 14 shows FACS plot indicating resistance of splenic germinal center B cells to short-term anti-CD20 mAb therapy. Mice were unimmunized or immunized with sheep red blood cells (SRBC) by intraperitoneal injection at day 1 to induce germinal centers in the spleen. The germinal centers appear by day 7. At
15   day 8, one group of mice was treated with anti-CD20 antibody m2H7. The control set of mice was treated with mIgG2a isotype control antibody. Spleen cells from the mice were analyzed at day 12. PNA (peanut agglutinin), which stains for germinal center, was utilized. No detectable germinal center cells were seen in the spleens of mice not immunized with SRBC whereas the spleens of immunized mice show 0.3%
20   PNA staining cells. While T2/Follicular B cells are depleted with anti-CD20 antibody treatment, marginal center B cells in the spleen are resistant to the antibody.

Figure 15 shows a T cell independent response in anti-CD20 mAb treated mice and controls. Mice were treated with m2H7 or isotype control antibody
25   mIgG2a at day 0. At days 3-7, B cell depletion has occurred. At day 7, the mice were injected i.v. with Streptococcus Pneumoniae IV to induce a response to the polysaccharide. A T cell independent response was mounted on day 11. The results demonstrate that treatment with anti-human CD20 m2H7 did not affect the B cell response from the marginal zone and B 1 cells, i.e., the non-depleted MZ and B1 B
30   cells confer protection to T-independent antigens.

Figure 16 shows a comparison of the effect of BR3 and 2H7 antibody treatment in Tg^{+} mice. Human CD20 transgenic mice expressing a bacterial artificial chromosome encoding human CD20 (designated as hCD20^{+} mice) were treated with intraperitoneal injections of anti-CD20 mAb (single injection of 100 micrograms on

day 9), BR3-Fc (100 micrograms every other day from days 1 through 12), or the combination of anti-CD20 mAb and BR3-Fc. Each group consisted of 4 mice. Two days following the last injection, the mice were sacrificed and analyzed for hCD20$^+$ B cells. FACS analysis of spleen, blood, lymph node and Peyer's Patches were

5    analyzed for B cell markers (CD21$^+$CD23$^+$). Anti-CD20 mAb therapy depleted T2 and follicular B cells, but not marginal zone B cells in the spleen, whereas BR3-Fc treatment decreased T2/follicular and marginal zone B cells in the spleen.

Figure 17 shows the lack of effect of anti-CD20 mAb treatment on Peyer's Patches. Human CD20 transgenic mice expressing a bacterial artificial chromosome

10   encoding human CD20 (designated as hCD20$^+$ mice) were treated with intraperitoneal injections of anti-CD20 mAb (single injection of 100 micrograms on day 9), BR3-Fc (100 micrograms every other day from days 1 through 12), or the combination of anti-CD20 mAb and BR3-Fc. Each group consisted of 4 mice. Two days following the last injection, the mice were sacrificed and analyzed for hCD20$^+$

15   B cells. FACS analysis of spleen, blood, lymph node and Peyer's Patches were analyzed for B cell markers (CD21$^+$CD23$^+$). Neither BR3-Fc nor 2H7 nor the combination of the two had an effect on germinal center B cells in Peyer's Patches

Figure 18 shows that plasma cells are not depleted following long-term anti-CD20 mAb treatment. Transgenic Tg$^+$ mice positive for human CD20 were treated

20   with anti-human CD20 mH27 antibody as described previously. The mice were analyzed for presence or absence of plasma cells by detecting cells in bone marrow and spleen that were positive for syndican (CD-138 plasma cell marker). The number of IgA or IgM positive plasma cells was also monitored after anti-human CD20 treatment. The results show that plasma cells in Tg$^+$ mice were not affected

25   by the anti-human CD20 antibody treatment, indicating that the Tg$^+$ mice still have the capacity to generate antibodies.

Figure 19 shows depletion of NK cells by PK-136 mAb in Tg$^+$ mice. Hybridoma clone, which produces PK-136 mAb (specific against mouse NK1.1), was obtained from ATCC. Four groups of human CD20 transgenic mice were

30   injected ip with control mAb, PK-136, anti-CD20 mAb and the combination of PK-136/anti-CD20, respectively. Doses administered ip were as follows:

            control mAb:      200ug/ip, 3 ip/week, for 1 week
            PK-136:           200ug/ip, 3 ip/week, for 1 week
            anti-CD20 mAb:  10 ug/ip, single dose

NK cells from peripheral blood, liver and spleen were analyzed after treatment with antibodies. Data is expressed as mean+/-standard error, with n=8.

Figure 20 shows that NK cells play a role in 2H7 mediated B cell depletion in Tg$^+$ mice. Hybridoma clone, which produces PK-136 mAb (specific against
5    mouse NK1.1), was obtained from ATCC. Four groups of human CD20 transgenic mice were injected ip with control mAb, PK-136, anti-CD20 mAb and the combination of PK-136/anti-CD20, respectively. Doses administered ip were as follows:

|  | control mAb: | 200ug/ip, 3 ip/week, for 1 week |
| 10 | PK-136: | 200ug/ip, 3 ip/week, for 1 week |
|  | anti-CD20 mAb: | 10 ug/ip, single dose |

Lymphocytes from peripheral blood, lymph nodes and spleen were analyzed 3 days after anti-CD20 mAb ip. Data is expressed as mean+/-standard error, with n=8.

Figure 21A shows an amino acid sequence for human CD20 (SEQ ID
15   NO: 1) (GenBank Accession No. BC002807), cDNA sequence for human CD20 (Figure 21B) (SEQ ID NO: 2) (GenBank Accession No. BC002807) and a genomic sequence for human CD20 (SEQ ID NO: 3) (GenBank Accession No. AH005353) (Figure 21C). Figure 21 D shows a cDNA sequence for murine CD20 (SEQ ID NO:4) (GenBank accession No. M62541).

20             Figure 22 shows a representative comparison of the expression level of  human CD20 expression on  peripheral blood cells from a human CD20 transgenic mouse as compared to expression of CD20 on human peripheral blood cells. Peripheral blood cells were obtained from a human donor and from a hCD20Tg+ mouse and stained with labelled anti-human CD20 antibody (mH27).
25   The cells were analyzed by FACS and were gated on human CD19+ and  B220+ populations. The numbers on the graph represent mean fluorescence intensity.


## Detailed Description

The following terms have the meanings ascribed to them below unless
30   specified otherwise.

The term "construct" or "targeting construct" refers to a polynucleotide molecule that comprises a targeting region. A targeting region comprises a sequence that is substantially homologous to an endogenous sequence in a target tissue, cell or animal and that provides for integration of the targeting construct into the genome of

the target tissue, cell or animal. Typically, the targeting construct will also include a gene or a nucleic acid sequence of particular interest, a marker gene and appropriate control sequences.

5    The term "CD20" refers to a cell surface protein that is expressed on certain cells of the immune system, specifically the B lymphocyte-restricted differentiation antigen Bp35. "Naturally occurring CD20" has an amino acid sequence of a protein obtained from nature and includes naturally occurring variants such as allelic variants, isotypes and truncated forms. More specifically, "CD20" includes human CD20 (AH003353; GenBank Accession nos. M27395, J03574). Representative

10   amino acid sequence, cDNA sequence and a genomic sequence of human and murine CD20 are shown in Figure 21. The invention also contemplates CD20 variants. The variants are changed as compared to a source sequence using generally known techniques and preferably retain the biological activity of a naturally occurring human CD20. Preferably the variants are not changed at amino

15   acid position 170 and 172 of a naturally occurring human CD20 as these positions · have been shown to be a part of the epitope recognized by several different anti-human CD20 monoclonal antibodies as described in Polyak et al., Blood 99:3256 (2002).

"Disruption" of a gene occurs when a fragment of DNA locates and

20   recombines with an endogenous homologous sequence. These sequence disruptions or modifications may include insertions, missense, frameshift, deletion, or substitutions, or replacements of DNA sequence, or any combination thereof. Insertions include the insertion of entire genes, which may be of animal, plant, fungal, insect, prokaryotic, or viral origin. Disruption, for example, can alter the

25   normal gene product by inhibiting its production partially or completely or by enhancing the normal gene product's activity. In a preferred embodiment, the disruption is a null disruption that has no significant expression of the gene.

By the term "endogenous loci" is meant to include the naturally occurring genetic loci found in the host animal that is to become transgenic.

30   The term "heterologous" when used in conjunction with polypeptide or gene refers to a polypeptide having an amino acid sequence or a DNA encoding the polypeptide that is not found in transgenic nonhuman host animal. Thus, a transgenic mouse having a human CD20 gene can be described as having a heterologous CD20 gene. The transgene can be detected using a variety of methods

9

including PCR, Western blot, or Southern blot. The term " human endogenous
promoter" refers to the promoter that is naturally associated with the polynucleotide
sequence that encodes the human protein that is to be introduced into the animal to
form a transgenic animal.

5          The term "non-human animals" is intended to include any vertebrate such as
mammals, birds, reptiles, and amphibians. Suitable mammals include rodents, non-
human primates, sheep, dogs and cows. Suitable birds include chickens, geese, and
turkeys. Preferred non-human animals are selected from the rodent family including
rat and mouse, most preferably mouse.

10         The term "naturally-occurring" or "naturally associated" as used herein as
applied to an object refers to the fact that an object can be found in nature. For
example, a polypeptide or polynucleotide sequence that is present in an organism
(including viruses) that can be isolated from a source in nature and which has not
been intentionally modified by man in the laboratory is naturally-occurring.

15         For nucleic acids, the term "substantial homology" indicates that two nucleic
acids, or designated sequences thereof, when optimally aligned and compared with
appropriate nucleotide insertions or deletions have at least about 80% sequence
identity, more preferably about 81% sequence identity, more preferably about 82%
sequence identity, more preferably about 83% sequence identity, more preferably
20   about 84% sequence identity, more preferably about 85% sequence identity, more
preferably about 86% sequence identity, more preferably about 87% sequence
identity, more preferably about 88% sequence identity, more preferably about 89%
sequence identity, more preferably about 90% sequence identity, more preferably
about 91% sequence identity, more preferably about 92% sequence identity, more
25   preferably about 93% sequence identity, more preferably about 94% sequence
identity, more preferably about 95% sequence identity, more preferably about 96%
sequence identity, more preferably about 97% sequence identity, more preferably
about 98% sequence identity, and more preferably about 99% sequence identity to
one another. Alternatively, substantial homology exists when the segments will
30   hybridize under selective hybridization conditions, to the complement of the strand.
Methods of aligning two sequences and identifying % identity are known to those of
skill in the art. Several computer programs are available for determining % identity.
Alignment for purposes of determining percent nucleic acid sequence identity can be
achieved in various ways that are within the skill in the art, for instance, using

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publicly available computer software such as BLAST, BLAST-2, ALIGN, ALIGN-2 or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for measuring alignment, including any algorithms needed to achieve maximal alignment over the full-length of the sequences being compared.

5      "Transcriptional regulatory sequence" refers to polynucleotide sequences, such as initiation signals, enhancers, and promoters, which induce or control transcription of protein coding sequences with which they are operably linked. In preferred embodiments, transcription of a recombinant transgene is under the control of a promoter sequence (or other transcriptional regulatory sequence), which

10    controls the expression of the recombinant gene in a cell-type in which expression is intended. It will also be understood that the recombinant gene can be under the control of transcriptional regulatory sequences which are the same or which are different from those sequences, which control transcription of a naturally-occurring form of CD20.

15    As used herein, the term "transgene" means a nucleic acid sequence (encoding, e.g., CD20 ) that has been introduced into a cell by way of human intervention such as by way of the described methods herein. A transgene could be partly or entirely heterologous, i.e., foreign, to the transgenic animal or cell into which it is introduced. A transgene can include one or more transcriptional

20    regulatory sequences and any other nucleic acid, such as introns, that may be necessary for optimal expression of a selected nucleic acid.

"Transgenic animal" or "Tg$^+$" are used interchangeably and are intended to include any non-naturally occurring non-human animal in which one or more of the cells of the animal contain heterologous nucleic acid encoding human CD20, that

25    has been introduced by way of human intervention, such as by transgenic techniques well known in the art. The nucleic acid is introduced into the cell, directly or indirectly by introduction into a precursor of the cell, by way of deliberate genetic manipulation, such as by microinjection or by infection with a recombinant virus. The term genetic manipulation does not include classical cross-breeding, but rather

30    is directed to the introduction of a recombinant DNA molecule. This molecule may be integrated within a chromosome, or it may be extrachromosomally replicating DNA. The term "Tg$^+$" includes animals that are heterozygous and/or homozygous for human CD20.

"CD20 associated disease" refers to diseases or disorders that have been associated with the expression of CD20 on cells, aberrant proliferation or activation of B cells, or have been treated with anti-CD20 antibodies. For example, a chimeric anti-CD20 antibody has been used to treat patients with lymphoma. Other diseases

5    or conditions that have been treated with anti-CD20 therapy include autoimmune conditions or diseases such as rheumatoid arthritis, systemic lupus erythromatosis, and ankylosing spondylitis. Other conditions include Epstein Barr virus associated disease following blood or bone marrow transplant, Karposi Sarcoma associated herpes virus related multicentric Castlemen disease, Hepatitis C associated

10   Cryoglobulinemia Vasculitis, lymphoproliferative disorders with autoimmune hemolytic anemia, and ANCA associated vasculitis.


A.    **Modes of the Invention**

The present invention provides transgenic animals expressing a heterologous

15   CD20 marker. In one embodiment, the human CD20 transgenic animals of the invention express CD20 on the same types of B cells as humans. Previous attempts to prepare transgenic mice expressing human CD20 may not have achieved expression of human CD20 in the appropriate B cell compartments or at sufficient levels due to lack of incorporation of effective transcriptional control regions into

20   the transgene.

The present invention provides a transgenic animal that has cells that react in a way that is similar to a human subject. Administration of anti-human CD20 antibodies to the presently described transgenic animals results in depletion of B lymphocytes expressing human CD20. In one embodiment, the human CD20

25   trangenic mice are characterized by expression of human CD20 on cells at a level sufficient for anti- human CD20 antibody bound to the expressing cells to affect killing of the cells, resulting in B cell depletion of peripheral and/or circulating B cells of at least about 75% and more preferably, 80%, 85%, 90%, 95% , 99% and even 100%. A similar response is observed in humans. These animal models can

30   be used for screening of agents including but not limited to monoclonal antibodies against the CD20 marker. Additionally, the transgenic animals may be used to test the efficacy and toxicity of anti-CD20 directed therapies.

**B.    DNA constructs**

Typically, a polynucleotide molecule encoding a heterologous protein of the invention is inserted into a vector, preferably a DNA vector, in order to replicate the polynucleotide molecule in a suitable host cell. DNA constructs may also be useful

5    to prepare targeting vectors for knockout animals.

In order to isolate, clone and transfer the CD20 locus, a yeast artificial chromosome (YAC) may be employed. The entire locus can be cloned and contained within one or a few YAC clones. If multiple YAC clones are employed and contain regions of overlapping homology, they can be recombined within yeast

10    host strains to produce a single construct representing the entire locus. YAC arms can be additionally modified with mammalian selection cassettes by retrofitting to assist in the introduction of the constructs into embryonic stems cells or embryos by the previously outlined methods.

Due to the high stability and relatively large inserts, ease of manipulation and

15    shotgun sequencing, bacterial artificial chromosome (BAC) libraries can provide human sequences for genes of interest. BAC libraries contain an average insert size of 100-150kb. BAC clones are capable of harboring inserts as large as 300,000 base pairs. Shizuya, et al., (1992) Proc. Natl. Acad. Sci., USA 89:8794-8797; Kim, et al., (1996) Genomics 34 213-218; Swiatek, et al., (1993) Genes and Development

20    7:2071-2084. Genomic BAC libraries of the human and mouse have been constructed and are commercially available (Invitrogen, Carlsbad CA). Genomic BAC libraries can also serve as a source of human and murine CD20 gene sequences as well as transcriptional control regions.

Nucleic acids encoding human CD20 are known to those of skill in the art.

25    Representative cDNA (SEQ ID NO: 2), genomic (SEQ ID NO: 3) and amino acid sequences (SEQ ID NO: 1) of human CD20 are shown in Figure 21. Other sequences can also be found in GenBank, such as Accession No. AH003353. Representative cDNA of murine CD20 (SEQ ID NO:4) is shown in Figure 21D.

The heterologous transgenes preferably comprise germline regulatory DNA

30    sequences operably linked to the gene of interest that is to be expressed in a transgenic non-human animal. By the term "operably linked" is meant a genetic sequence operationally (i.e., functionally) linked to a nucleic acid segment, or sequences upstream (5') or downstream (3') from a given segment or sequence.

13

Those nearby sequences often impact processing and/or expression of the nucleic acid segment or sequence in a desired cell type.

Preferably, these regulatory sequences are genomic in origin, and include one or more introns. For example, the transgenic construct can include regulatory
5   regions located in the 5'-flanking regions of a gene encoding CD20 operably linked to the coding sequences in a manner capable of replicating and expressing the gene in a host cell. In one embodiment, the regulatory sequences comprise the endogenous promoter sequence naturally associated with human CD20. In some embodiments, the promoters provide for tissue specific expression at a level similar
10  to that level of expression in the animal from which the sequence is derived. If additional flanking sequences are useful in optimizing expression, such sequences can be cloned using the existing sequences as probes. Additional sequences necessary for maximizing processing or expression of the transgene can be derived from genomic sequences.

15         Alternatively, the promoters can be those promoters associated with the corresponding endogenous gene in the transgenic host animal. For example, if the murine genes CD20 genes are disrupted by integration with the corresponding human genes, the corresponding human genes are preferably integrated so as to be operably linked to murine transcriptional control regions for the endogenous murine
20  CD20.

Preferably, the regulatory sequences provide for expression of the transgene in the appropriate cells and at a level so that expression can be detected using standard methodologies such as detection with antibodies. In one embodiment, the regulatory sequences provide for expression of the human CD20 transgene at a level
25  at least 40% of the expression of CD20 on human cells.

An expression system or construct encoding a transgene as described herein can also include a 3' untranslated region downstream of the DNA sequence. Such regions can stabilize the RNA transcript of the expression system and thus increases the yield of desired protein from the expression system. Among the 3' untranslated
30  regions useful in the constructs of this invention are sequences that provide a poly A signal. Such sequences may be derived, e.g., from the SV40 small t antigen, the CD20 untranslated region or other 3' untranslated sequences well known in the art.

Optionally, the expression system or construct includes a 5' untranslated region between the promoter and the DNA sequence encoding the signal sequence.

14

Such untranslated regions can be from the same control region from which promoter is taken or can be from a different gene, e.g., they may be derived from other synthetic, semi-synthetic or natural sources.

In addition, other promoters or other transcriptional regulatory sequences not

5    naturally associated with the transgene may be utilized. For example, heterologous promoters may provide for enhanced levels of expression or tissue specific expression. Various promoters having different strengths may be utilized as long the promoter functions in the non-human animal or in the desired tissue type. Many promoters are known to those of skill in the art.

10   Expression systems can be prepared using methods known in the art. For example, an expression system can be prepared as part of a larger plasmid. Such preparation allows the cloning and selection of the correct constructions in an efficient manner as is known in the art. Expression systems can be located between convenient restriction sites on the plasmid so that they can be easily isolated from

15   the remaining plasmid sequences for incorporation into the desired mammal. Preferably, the DNA construct encoding the human CD20 comprises a bacterial artificial chromosome including the naturally associated transcriptional regulatory sequences to provide for tissue specific expression.

The various methods employed in the preparation of the plasmids and

20   transformation of host organisms are known in the art. For other suitable expression systems for both prokaryotic and eukaryotic cells, as well as general recombinant procedures, see Molecular Cloning A Laboratory Manual, 2nd Ed., ed. by Sambrook, Fritsch and Maniatis (Cold Spring Harbor Laboratory Press: 1989) Chapters 16 and 17.

25

## C.    Production of Transgenic Animals

Methods for generating transgenic animals of the present invention, including knock-outs and knock-ins, are well known in the art (see, generally, Gene Targeting: A Practical Approach, Joyner, ed., Oxford University Press, Inc. (2000)).

30   In one embodiment, generation of the transgenic mice may optionally involve disruption of the genetic loci of the murine marker and introduction of the gene encoding the human marker into the murine genome, preferably at the same location as the endogenous gene.

According to the invention, a transgenic mouse model is generated where the human CD20 has been introduced into the murine genome (huCD20$^+$; alternatively referenced as huCD20Tg$^+$). An endogenous murine CD20 polypeptide is present on murine lymphocytes, but the known anti-human CD20 monoclonal antibodies do not

5    bind to murine B cells. The endogenous murine CD20 gene, therefore, does not have to be but can be disrupted, if desired. When the endogenous murine CD20 is not disrupted then the gene encoding human CD20 is preferably inserted at a location other than that of the gene encoding murine CD20.

10       **Inactivation of Endogenous Loci**

In a preferred embodiment, inactivation of the endogenous loci is achieved by targeted disruption through homologous recombination in embryonic stem cells. In one embodiment, DNA is introduced into a host cell and recombines at the endogenous loci to disrupt the production of endogenous CD20. The targeting

15   construct may be produced using standard methods known in the art (see, e.g., Sambrook et al., 1989, Molecular Cloning: A Laboratory Manual, Second Edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York; E.N. Glover (eds.), 1985, DNA Cloning: A Practical Approach, Volumes I and II; M.J. Gait (ed.), 1984, Oligonucleotide Synthesis; B.D. Hames & S.J. Higgins (eds.), 1985,

20   Nucleic Acid Hybridization; B.D. Hames & S.J. Higgins (eds.), 1984, Transcription and Translation; R.I. Freshney (ed.), 1986, Animal Cell Culture; Immobilized Cells and Enzymes, IRL Press, 1986; B. Perbal, 1984, A Practical Guide To Molecular Cloning; F.M. Ausubel et al., 1994, Current Protocols in Molecular Biology, John Wiley & Sons, Inc.). For example, the targeting construct may be prepared in

25   accordance with conventional ways, where sequences may be synthesized, isolated from natural sources, manipulated, cloned, ligated, subjected to in vitro mutagenesis, primer repair, or the like. At various stages, the joined sequences may be cloned, and analyzed by restriction analysis, sequencing, or the like.

The targeting DNA can be obtained using techniques well known in the art.

30   For example, the targeting DNA may be produced by chemical synthesis of oligonucleotides, nick-translation of a double-stranded DNA template, polymerase chain-reaction amplification of a sequence (or ligase chain reaction amplification), purification of prokaryotic or target cloning vectors harboring a sequence of interest (e.g., a cloned cDNA or genomic DNA, synthetic DNA or from any of the

aforementioned combination) such as plasmids, phagemids, YACs, cosmids, BACs, bacteriophage DNA, other viral DNA or replication intermediates, or purified restriction fragments thereof, as well as other sources of single and double-stranded polynucleotides having a desired nucleotide sequence. Moreover, the length of

5    homology may be selected using known methods in the art. For example, selection may be based on the sequence composition and complexity of the predetermined endogenous target DNA sequence(s).

        In one embodiment, the targeting construct of the present invention comprises a targeting region, which comprises a first sequence (or arm) homologous

10    to a portion or region of the CD20 gene to be disrupted and a second sequence homologous to a second portion or region of the gene. The targeting construct may further comprise a positive selection marker, which is preferably positioned between the first and the second DNA sequences. The positive selection marker may be operatively linked to a promoter and a polyadenylation signal.

15        In another embodiment, the targeting construct may contain more than one selectable maker gene, including a negative selectable marker, such as the herpes simplex virus tk (HSV-tk) gene, which is preferably positioned outside one or both of the homologous arms of the targeting construct. The negative selectable marker may be operatively linked to a promoter and a polyadenylation signal (see, e.g., U.S.

20    Patent Nos. 5,464,764; 5,487,992; 5,627,059 and 5,631,153).

        Once an appropriate targeting construct has been prepared, the targeting construct may be introduced into an appropriate host cell using any method known in the art. Various techniques may be employed in the present invention, including, for example: pronuclear microinjection; retrovirus mediated gene transfer into germ

25    lines; gene targeting in embryonic stem cells; electroporation of embryos; sperm-mediated gene transfer; and calcium phosphate/DNA co-precipitates, microinjection of DNA into the nucleus, bacterial protoplast fusion with intact cells, transfection, polycations, e.g., polybrene, polyornithine, etc., or the like (see, e.g., U.S. Patent No. 4,873,191; Van der Putten et al., 1985, Proc. Natl. Acad. Sci., USA 82:6148-6152;

30    Thompson et al., 1989, Cell 56:313-321; Lo, 1983, Mol Cell. Biol. 3:1803-1814; Lavitrano et al., 1989, Cell, 57:717-723). Various techniques for transforming mammalian cells are known in the art. (see, e.g., Gordon, 1989, Intl. Rev. Cytol., 115:171-229; Keown et al., 1989, Methods in Enzymology; Keown et al., 1990,

Methods and Enzymology, Vol. 185, pp. 527-537; Mansour et al., 1988, Nature, 336:348-352).

Any cell type capable of homologous recombination may be used in the practice of the present invention. Examples of such target cells include cells derived from vertebrates including mammals such as humans, bovine species, ovine species, murine species, simian species, and ether eukaryotic organisms such as filamentous fungi, and higher multicellular organisms such as plants.

Preferred cell types include embryonic stem (ES) cells, which are typically obtained from pre-implantation embryos cultured in vitro (see, e.g., Evans, M. J. et al., 1981, Nature 292:154-156; Bradley, M. O. et al., 1984, Nature 309:255-258; Gossler et al., 1986, Proc. Natl. Acad. Sci. USA 83:9065-9069; and Robertson et al., 1986, Nature 322:445-448). The ES cells are cultured and prepared for introduction of the targeting construct using methods well known to the skilled artisan. (see, e.g., Robertson, E. J. ed. "Teratocarcinomas and Embryonic Stem Cells, a Practical Approach", IRL Press, Washington D.C., 1987; Bradley et al., 1986, Current Topics in Devel. Biol. 20:357-371; by Hogan et al., in "Manipulating the Mouse Embryo": A Laboratory Manual, Cold Spring Harbor Laboratory Press, Cold Spring Harbor N.Y., 1986; Thomas et al., 1987, Cell 51:503; Koller et al., 1991, Proc. Natl. Acad. Sci. USA, 88:10730; Dorin et al., 1992, Transgenic Res. 1:101; and Veis et al., 1993, Cell 75:229). The ES cells that will be inserted with the targeting construct are derived from an embryo or blastocyst of the same species as the developing embryo into which they are to be introduced. ES cells are typically selected for their ability to integrate into the inner cell mass and contribute to the germ line of an individual when introduced into the mammal in an embryo at the blastocyst stage of development. Thus, any ES cell line having this capability is suitable for use in the practice of the present invention.

After the targeting construct has been introduced into cells, the cells in which successful gene targeting has occurred are identified. Insertion of the targeting construct into the targeted gene is typically detected by identifying cells for expression of the marker gene. In a preferred embodiment, the cells transformed with the targeting construct of the present invention are subjected to treatment with an appropriate agent that selects against cells not expressing the selectable marker. Only those cells expressing the selectable marker gene survive and/or grow under certain conditions. For example, cells that express the introduced neomycin

18

resistance gene are resistant to the compound G418, while cells that do not express the neo gene marker are killed by G418. If the targeting construct also comprises a screening marker such as GFP, homologous recombination can be identified through screening cell colonies under a fluorescent light. Cells that have undergone

5    homologous recombination will have deleted the GFP gene and will not fluoresce.

Alternatively, a positive-negative selection technique may be used to select homologous recombinants. This technique involves a process in which a first drug is added to the cell population, for example, a neomycin-like drug to select for growth of transfected cells, i.e. positive selection. A second drug, such as FIAU, is

10   subsequently added to kill cells that express the negative selection marker, i.e. negative selection. Cells that contain and express the negative selection marker are killed by a selecting agent, whereas cells that do not contain and express the negative selection marker survive. For example, cells with non-homologous insertion of the construct express HSV thymidine kinase and therefore are sensitive

15   to the herpes drugs such as gancyclovir (GANC) or FIAU (1-(2-deoxy 2-fluoro-B-D-arabinofluranosyl)-5-iodouracil). (see, e.g., Mansour et al., Nature 336:348-352: (1988); Capecchi, Science 244:1288-1292, (1989); Capecchi, Trends in Genet. 5:70-76 (1989)). Other methods include regulated positive selection (see U.S. 20030032175A1), which requires the addition of a single selective agent.

20   Successful recombination may be identified by analyzing the DNA of the selected cells to confirm homologous recombination. Various techniques known in the art, such as PCR and/or Southern analysis may be used to confirm homologous recombination events.

Selected cells are then injected into a blastocyst (or other stage of

25   development suitable for the purposes of creating a viable animal, such as, for example, a morula) of an animal (e.g., a mouse) to form chimeras (see e.g., Bradley, A. in Teratocarcinomas and Embryonic Stem Cells: A Practical Approach, E. J. Robertson, ed., IRL, Oxford, pp. 113-152 (1987)). Alternatively, selected ES cells can be allowed to aggregate with dissociated mouse embryo cells to form the

30   aggregation chimera. A chimeric embryo can then be implanted into a suitable pseudopregnant female foster animal and the embryo brought to term. Chimeric progeny harboring the homologously recombined DNA in their germ cells can be used to breed animals in which all cells of the animal contain the homologously recombined DNA. In one embodiment, chimeric progeny mice are used to generate

a mouse with a heterozygous disruption in the CD20 gene. Heterozygous
transgenic mice can then be mated. It is well known in the art that typically ¼ of the
offspring of such matings will have a homozygous disruption in the CD20 gene.

5      In addition to the above described methods of inactivation of endogenous
loci, additional preferred methods of inactivation are available and may include for
example, use of the tet transcription system to utilize temporal control of specific
genes of interest (Proc. Natl. Acad. Sci. 91:9302-9306 (1994)) or introduction of
deoxycycline transcriptional regulatory controls for tissue specific control (Proc.
Natl. Acad. Sci. 93:10933-10938 (1996)).

10     An additionally preferred method for functional inactivation includes
employment of the cre-lox deletion, site specific recombination system for targeted
knock-out of genetic loci, wherein loxP sites are inserted to flank genes of interest
and cre recombinase activated to delete genes (Curr. Opin. Biotechnol., 5:521-527
(1994)).

15     Alternatively, antisense or RNAi methods may be utilized in order to inhibit
transcription of the desired loci, thus resulting in functional disruption of
endogenous loci (knock-down methods). In such a situation, oligonucleotides are
generated which target specific sequences of the designated locus of interest,
wherein successful targeting results in inhibited production of the functional protein.

20     Knock-out mice homozygous for the loss of endogenous CD20 can be
prepared as described in WO 02/062946. Briefly, in one embodiment, CD20-
deficient mice can be generated by targeted disruption of the murine CD20 gene in
embryonic stem (ES) cells using homologous recombination. A targeting vector can
be generated that replaces exons encoding part of the second extracellular loop, the

25     4th transmembrane domain, and the large carboxyl-terminal cytoplasmic domain of
murine CD20 with a neomycin resistance gene. The nucleotide sequence of murine
CD20 is known to those of skill in the art. (GenBank accession No.
M62541;WO02/062946)). In one embodiment, appropriate gene targeting generates
an aberrant CD20 protein truncated at amino acid position 157 and fused with an 88

30     amino acid protein encoded by the Neo gene sequence.

After DNA transfection, neo-resistant ES cell clones carrying the targeted
allele can be determined by Southern blot analysis. Cells of one ES cell clone can
be injected into blastocysts that can be transferred into foster mothers. Highly
chimeric male offspring (80-100% according to coat color) can be bred with

C57BL/6 (B6) females for transmitting the mutation to their progeny. Mice homozygous for disruption of the CD20 gene can be obtained at the expected Menedelian frequency by crossing heterozygous offspring.

Appropriate targeting of the CD20 can be further verified by PCR analysis of
5    genomic DNA from homozygous offspring. Presence or absence of wild type CD20 mRNA in CD20$^{-/-}$ mice can be confirmed by PCR amplification of cDNA generated from splenocytes of CD20$^{-/-}$ mice. Absence of cell surface CD20 protein expression in CD20$^{-/-}$ mice can be further verified by staining B220$^{+}$ splenocytes with murine anti-CD20 monoclonal antibodies. Targeted mutation of the CD20 gene abrogates
10    cell surface CD20 protein expression.

### Introducing Transgenes into Non-Human Animal

The transgenic non-human animals of the invention are preferably produced by introducing transgenes into the germline of the animal. Embryonic target cells at
15    various developmental stages can be used to introduce transgenes. Different methods are used depending on the stage of development of the embryonic target cell. The specific line(s) of any animal used to practice this invention are selected for general good health, good embryo yields, good pronuclear visibility in the embryo, and good reproductive fitness. When transgenic mice are to be produced,
20    strains such as C57BL/6 or C57BL/6 x DBA/2 F$_1$, or FVB lines are often used (obtained commercially from Charles River Labs, Boston, Mass., The Jackson Laboratory, Bar Harbor, ME, or Taconic Labs.). Preferred strains are those with H-2$^b$, H-2$^d$ or H-2$^q$ haplotypes such as C57BL/6 or DBA/1. In addition, nude mice may be employed to provide for introduction of human tumor cells into the
25    transgenic mice. Breeding and maintenance of transgenic nude mice are more difficult because the mice are more susceptible to infection and disease. The line(s) used to practice this invention may themselves be transgenics, and/or may be knockouts. Preferably the same line will be used for preparation of both the initial knockout mammals and the transgenic mammals. This will make subsequent
30    breeding and backcrossing more efficient.

Introduction of the transgene into the embryo can be accomplished by any means known in the art such as, for example, microinjection, electroporation, or lipofection. For example, the transgene can be introduced into a mammal by microinjection of the construct into the pronuclei of the fertilized mammalian egg(s)

to cause one or more copies of the construct to be retained in the cells of the

developing mammal(s). Following introduction of the transgene construct into the

fertilized egg, the egg may be incubated in vitro for varying amounts of time, or

reimplanted into the surrogate host, or both. In vitro incubation to maturity is within

5      the scope of this invention. One common method is to incubate the embryos in vitro

for about 1-7 days, depending on the species, and then reimplant them into the

surrogate host.

Reimplantation is accomplished using standard methods. Usually, the

surrogate host is anesthetized, and the embryos are inserted into the oviduct. The

10     number of embryos implanted into a particular host will vary by species, but will

usually be comparable to the number of off spring the species naturally produces.

Retroviral infection can also be used to introduce transgene into a non-

human animal. The developing non-human embryo can be cultured in vitro to the

blastocyst stage. During this time, the blastomeres can be targets for retroviral

15     infection (Jaenich, R. (1976) PNAS 73:1260-1264). Efficient infection of the

blastomeres is obtained by enzymatic treatment to remove the zona pellucida

(Manipulating the Mouse Embryo, Hogan eds. (Cold Spring Harbor Laboratory

Press, Cold Spring Harbor, 1986). The viral vector system used to introduce the

transgene is typically a replication-defective retrovirus carrying the transgene

20     (Jahner et al. (1985) PNAS 82:6927-6931; Van der Putten et al. (1985) PNAS

82:6148-6152). Transfection is easily and efficiently obtained by culturing the

blastomeres on a monolayer of virus-producing cells (Van der Putten, supra; Stewart

et al. (1987) EMBO J. 6:383-388). Alternatively, infection can be performed at a

later stage. Virus or virus-producing cells can be injected into the blastocoele

25     (Jahner et al. (1982) Nature 298:623-628). Most of the founders will be mosaic for

the transgene since incorporation occurs only in a subset of the cells which formed

the transgenic non-human animal. Further, the founder may contain various

retroviral insertions of the transgene at different positions in the genome which

generally will segregate in the offspring. In addition, it is also possible to introduce

30     transgenes into the germ line by intrauterine retroviral infection of the midgestation

embryo (Jahner et al. (1982) supra).

A third type of target cell for transgene introduction is the embryonic stem

cell. Transgenes can be efficiently introduced into the ES cells by DNA transfection

or by retrovirus-mediated transduction. Such transformed ES cells can thereafter be

combined with blastocysts from a non-human animal. The ES cells thereafter colonize the embryo and contribute to the germ line of the resulting chimeric animal.

In one embodiment, a cDNA or genomic clone encoding human CD20 such as shown in Figure 21 can be introduced into FVB mice fertilized eggs or ES cells

5      using microinjection or transfection. The embryos are incubated in vitro from about 1-7 days and then implanted into a surrogate host. The ES cells are combined with blastocysts from naturally mated host animals and the blastocysts are reimplanted into surrogate mothers.

In one embodiment of the invention, an endogenous CD20 gene in a

10     nonhuman host is functionally disrupted by homologous integration of a heterologous CD20, such that the heterologous CD20 gene substantially replaces the endogenous CD20 gene, and preferably completely replaces the coding sequences of the endogenous CD20 gene. Preferably, the heterologous CD20 gene is linked, as a consequence of homologous integration, to regulatory sequences (e.g., an enhancer

15     promoter) of the endogenous CD20 gene, respectively, so that the heterologous gene is expressed under the transcriptional control of regulatory elements from the endogenous CD20 gene locus. Nonhuman hosts which are homozygous for such replacement alleles may be produced according to methods described herein. Such homozygous nonhuman hosts generally will express a heterologous CD20 but do

20     not express the endogenous CD20 protein. Usually, the expression pattern of the heterologous CD20 gene will substantially mimic the expression pattern of the endogenous CD20 gene, in the naturally-occurring (non-transgenic) nonhuman host.

For example, a transgenic mouse can be generated that has human CD20 gene sequences in place of endogenous murine CD20 gene sequences and which are

25     transcriptionally controlled by endogenous murine regulatory sequences. The human CD20 generally will be expressed similarly to the murine CD20 in naturally occurring non-transgenic mice.

Generally, a replacement-type targeting construct is employed for homologous gene replacement. Double-crossover homologous recombination

30     between endogenous CD20 gene sequences of the targeting construct result in targeted integration of the heterologous CD20 gene segments. Usually, the homology targeting regions of the transgene comprise sequences which flank the endogenous CD20 gene segments, so that homologous recombination results in concomitant deletion of the endogenous CD20 , and homologous integration of the

23

heterologous gene segments. Substantially an entire endogenous CD20 gene may be replaced with a heterologous CD20 by a single targeting event or by multiple targeting events (e.g., sequential replacement of individual exons). One or more selectable markers, usually in the form of positive or negative selection expression

5      cassettes, may be positioned in the targeting construct. It is usually preferred that selectable markers are located in intron regions of the heterologous replacement region.

### Crossing of Transgenic Mice

10     Transgenic mice comprising transgene human CD20 can be crossed with transgenic mice lacking the murine CD20. In one embodiment, the transgenic mouse comprises the human CD20 and lacks the murine CD20. A manner of preparation is to generate a series of mammals, each containing one of the desired knockout constructs or transgenes. Such mammals are bred together through a

15     series of crosses, backcrosses and selections, to ultimately generate a single mammal containing all desired knockout constructs and/or transgenes, where the mammal is otherwise congenic (genetically identical) to the wild type except for the presence of the knockout(s) constructs and/or transgene(s).

Typically, crossing and backcrossing is accomplished by mating siblings or a

20     parental strain with an offspring, depending on the goal of each particular step in the breeding process. In certain cases, it may be necessary to generate a large number of offspring in order to generate a single offspring that contains each of the knockout constructs and/or transgenes in the proper chromosomal location. In addition, it may be necessary to cross or backcross over several generations to ultimately obtain the

25     desired genotype.

Once the human loci have been introduced into the host genome, either by homologous recombination or random integration, and host animals have been produced with the endogenous CD20 loci inactivated by appropriate breeding of the various transgenic or mutated animals, one can produce a host which lacks the

30     native capability to produce endogenous CD20, but has the capacity to produce human CD20.

## D.    Verification of the Presence of Transgenes

Transgenic offspring of the surrogate host may be screened for the presence and/or expression of the transgene in the desired tissue, cell or animal by any suitable method. Screening is often accomplished by Southern blot or Northern blot

5    analysis, using a probe that is complementary to at least a portion of the transgene. Western blot analysis using an antibody against the protein encoded by the transgene may be employed as an alternative or additional method for screening for the presence of the transgene product. Typically, DNA is prepared from tail tissue and analyzed by Southern analysis or PCR for the transgene. Alternatively, the tissues or

10    cells believed to express the transgene at the highest levels are tested for the presence and expression of the transgene using Southern analysis or PCR, although any tissues or cell types may be used for this analysis.

Alternative or additional methods for evaluating the presence of the transgene include, without limitation, suitable biochemical assays such as enzyme

15    and/or immunological assays, histological stains for particular marker or enzyme activities, flow cytometric analysis, and the like. Analysis of the blood may also be useful to detect the presence of the transgene product in the blood, as well as to evaluate the effect of the transgene on the levels of various types of blood cells and other blood constituents. In one embodiment, expression of human CD20 can be

20    detected on immune cells from spleen, bone marrow, peripheral blood, lymph nodes, and Peyer's Patches using a detectably labeled antibody to human CD20 and analyzing the labeled cells using FACS.

Examination of expression patterns in the transgenic mice of the present invention reveals a mirroring of normal human CD20 expression found in human B

25    lineage cells. Other immunological parameters examined in terms of percentage of cells and phenotypic characteristics, including those of T cells, B cells, NK cells, macrophages, dendritic cells and neutrophils, revealed a similarity between transgenic negative and positive littermates.

30    ## E.    Uses of Transgenic Animals

Transgenic animals of the present invention represent models of CD20 expression and function in humans. Accordingly, these animals are useful in studying the mechanisms behind their function and related events, and to generate and test products (e.g., antibodies, bispecifics, multispecifics etc.) useful in treating

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and diagnosing CD20 associated human diseases, including cancer and autoimmune conditions.

In some embodiments, transgenically expressed human CD20 retain similar functional properties as are exhibited in human cells. For example, B lymphocytes

5   expressing human CD20 are recognized by anti-human CD20 antibodies and as in the human, are similarly depleted from the transgenic animal in response to administration of human CD20 antibody. As described in further detail in the Examples, B lymphocytes in the transgenic mice of the present invention are depleted in response to treatment with anti-human CD20 antibodies such as Rituxan.

10  In one embodiment, the human CD20 trangenic mice are characterized by expression of human CD20 on cells at a level sufficient for anti- human CD20 antibody bound to the expressing cells to affect killing of the cells, resulting in B cell depletion of peripheral and/or circulating B cells of at least about 75% and more preferably, 80%, 85%, 90%, 95% , 99% and even 100%. A similar response is

15  observed in humans.

Accordingly, in one embodiment the transgenic animals of the invention are used to test agents such as antibodies, multi- or bispecific molecules, immunoadhesins (e.g., for human safety and efficacy) for binding to target epitopes, such as a region of a human CD20. Other agents can include antigen binding

20  fragments of antibodies with or without Fc regions, single chain antibodies, minibodies (heavy chain only antibodies), heteromultimeric immunoadhesins with one of the multimers anti-human CD20 antigen binding region. Other agents may include small molecules that inhibit or result in CD20-B cell depletion that may include variants of ligands of CD20 that bind to, but do not activate CD20. For

25  example, the effectiveness of such agents to deplete CD20 expressing cells such as malignant B cells can be determined by measuring B lymphocyte levels in the transgenic animals before and after administration of the test agent.

Accordingly, the present invention provides methods of identifying agents capable of treating a B cell lymphoma, as well as agents capable of depleting or

30  killing B lymphocytes expressing human CD20, by administering an agent to a transgenic animal that expresses human CD20 and determining whether there is a reduction in the number of B lymphocytes. As used herein, "B cell depletion" refers to a reduction in B cell levels in an animal or human after drug or antibody treatment as compared to the level before such treatment. B cell levels are measurable using

26

well known assays as described herein. B cell depletion can be partial or complete. Preferably, the level of B cell depletion induced by the agent is an amount that correlates with a decrease or amelioration of the symptoms of the disease or disorder. The effectiveness of the putative agent (i.e., its ability to deplete B

5    lymphocytes expressing CD20) can be assessed by measuring baseline levels of circulating B lymphocytes in a transgenic animal expressing CD20 and comparing with levels after administration in the same animal. A comparison of efficacy for B cell depletion can be made to known therapeutic agents such as anti-human CD20 antibodies (e.g. Rituxan ) to gauge effectiveness of the putative agent for treatment

10   for CD20 associated conditions. Alternatively, baseline levels of B lymphocytes can be measured in the various tissues (e.g., spleen, bone marrow, peripheral blood, lymph nodes, Peyer's Patches) of a first transgenic animal expressing human CD20. The putative agent can then be administered to a second transgenic animal expressing human CD20. The animal is then sacrificed and the level of B

15   lymphocytes analyzed. A reduction in the number of B lymphocytes in a transgenic animal expressing human CD20 is an indication of the agents' effectiveness in reducing cancerous cells associated with a B cell lymphoma, and/or treating a B cell lymphoma in a human subject. Combination therapies may also be tested to determine the effectiveness of depleting the desired cell types. For example, an anti-

20   human CD20 antibody can be combined with another agent such as Br3-Fc to cause depletion of any CD20 bearing B cells that may be resistant to killing by anti-human CD20.

        B lymphocyte recovery can also be assessed by measuring cell levels over time in a series of transgenic animals. The specificity of the agent for human CD20

25   can be assessed by comparing the agents' effect on transgenic mice expressing human CD20 with the effect on wild type mice (which do not express a CD20 marker). The effectiveness of the agent can also be compared with the effect of a placebo or control substance such as a non-specific Ab or other control agent. Preferably, the agent targets most or all cells bearing human CD20 and but does not

30   affect cells providing immune responsiveness to antigens that stimulate a T independent immune response.

        In addition, the animals are useful models for assessing the potential immune response in a human as the initiation of an immune response in the transgenic animal upon administration of such agents is indicative that the agents will produce the

same effect in humans. An effect on the immune response in such a transgenic animal can be detected for example by a change in cytokine levels, production of an antibody or a T cell response. In addition, the transgenic animal can be engineered to contain target cells (e.g. tumor, virus) prior to administration of the multi- or

5    bispecific molecule.

To detect antibody binding following administration of an anti-CD20 antibody, or bi- or multispecific molecule to a transgenic animal, any suitable assay can be used. For example, a sample of the animal's blood can be taken and assayed for the presence of anti-CD antibody-CD complexes using screening assays known

10    in the art, such as an enzyme-linked immunosorbent assay (ELISA), a radioimmunoassay (RIA), or a Western Blot Assay. Each of these assays generally detects the presence of protein-antibody complexes of particular interest by employing a labeled reagent (e.g., an antibody) specific for the complex of interest. Accordingly, in the present invention, these assays are used to detect CD-antibody

15    complexes formed between immunoglobulins (e.g., IgG, IgA etc.) contained in the animal's blood serum and human CD markers contained on the surface of particular cells in the animal.

The CD marker-antibody complexes can be detected using e.g., an enzyme-linked antibody or antibody fragment that recognizes and specifically binds to the

20    antibody-CD marker complexes. Alternatively, the complexes can be detected using any of a variety of other immunoassays. For example, the antibody can be radioactively labeled and used in a radioimmunoassay (RIA). The radioactive isotope can be detected by such means as the use of a gamma counter or a scintillation counter or by autoradiography.

25    To detect an immune response following administration of an antibody, or bi- or multispecific molecule or other agent to a transgenic animal, any suitable procedure for measuring a change in the concentration of e.g., a cytokine, antibody or T cell population in the plasma or serum of the animal can be used. For example, a change in a cytokine concentration in vivo can be detected via a variety of

30    immunoassays, such as enzyme immunoassay (EIA), radioimmunoassay (RIA) or ELISPOT assay. Exemplary cytokines that can be assayed include: granulocyte/macrophage colony stimulating factor (GM-CSF), granulocyte colony-stimulating factor (G-CSF), macrophage colony-stimulating factor (M-CSF), interleukins 1-12 (IL-1 to IL-12).

For example, plasma can be obtained from a transgenic animal to which an antibody, bispecific, or multi specific molecule or other agent has been administered. The concentration of a cytokine can be measured using an EIA by detecting the interaction of the cytokine with an antibody, which is in turn

5   conjugated to an enzyme. The activity of the enzyme is detected by the reaction with an appropriate substrate, preferably a chromogenic substrate, in such a manner as to produce a chemical moiety which can be detected, for example, by spectrophotometric, fluorimetric or by visual means (Voller, "The Enzyme Linked Immunosorbent Assay (ELISA)", Diagnostic Horizons 2:1-7, 1978, Microbiological

10  Associates Quarterly Publication, Walkersville, MD; Voller, et al., J. Clin. Pathol. 31:507-520 (1978); Butler, Meth. Enzymol. 73:482-523 (1981); Maggio, (ed.) Enzyme Immunoassay, CRC Press, Boca Raton, FL, 1980; Ishikawa, et al., (eds.) Enzyme Immunoassay, Kgaku Shoin, Tokyo, 1981). Enzymes which can be used to detectably label the antibody include, but are not limited to, malate dehydrogenase,

15  staphylococcal nuclease, delta-5-steroid isomerase, yeast alcohol dehydrogenase, alpha-glycerophosphate, dehydrogenase, triose phosphate isomerase, horseradish peroxidase, alkaline phosphatase, asparaginase, glucose oxidase, beta-galactosidase, ribonuclease, urease, catalase, glucose-6-phosphate dehydrogenase, glucoamylase and acetylcholinesterase. The detection can be accomplished by colorimetric

20  methods which employ a chromogenic substrate for the enzyme. Detection may also be accomplished by visual comparison of the extent of enzymatic reaction of a substrate in comparison with similarly prepared standards or using RIA.

It is also possible to label the anti-cytokine antibody or anti-CD20 molecule with a fluorescent compound. When the fluorescently labeled antibody is exposed

25  to light of the proper wave length, its presence can then be detected. Among the most commonly used fluorescent labeling compounds are fluorescein isothiocyanate, rhodamine, phycoerythrin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine. The antibody can also be detectably labeled using fluorescence emitting metals such as 152Eu, or others of the lanthanide series. These metals can

30  be attached to the antibody using such metal chelating groups as diethylenetriaminepentacetic acid (DTPA) or ethylenediaminetetraacetic acid (EDTA). The antibody also can be detectably labeled by coupling it to a chemiluminescent compound. The presence of the chemiluminescent-tagged antibody is then determined by detecting luminescence that arises during the course

of a chemical reaction. Examples of particularly useful chemiluminescent labeling compounds are luminol, isoluminol, theromatic acridinium ester, imidazole, acridinium salt and oxalate ester. Likewise, a bioluminescent compound may be used to label the antibody. Bioluminescence is a type of chemiluminescence found in biological systems in, which a catalytic protein increases the efficiency of the chemiluminescent reaction. The presence of a bioluminescent protein is determined by detecting the presence of luminescence. Important bioluminescent compounds for purposes of labeling are luciferin, luciferase and aequorin.

A non-human transgenic animal of the present invention can further provide an indication of the safety of a particular agent for administration to a human. For example, a humanized antibody or other agent can be administered to the transgenic animal and any toxic or adverse effects as a result of the administration of the agent to the animal can be monitored or identified as an indication of the safety and tolerability of the humanized antibody or agent for in vivo human use. Adverse events that may occur on a short term basis include headache, infection, fever, chills, pain, nausea, asthenia, pharyngitis, diarrhea, rhinitis, infusion reactions, and myalgia. Short term adverse events are measured in days post treatment. Long term adverse effects include cytoxicity of certain cell types, bleeding events due to thrombocytopenia, release of mediators due to inflammatory and/or allergic reactions, inhibition of the immune system and/or development of an anti-therapeutic agent antibody, end organ toxicity, and increased incidence of infection or malignancy. Long term adverse events are measured in months post treatment.

Another aspect of the invention involves a method for determining efficacy of an anti-CD20 agent. Efficacy can be determined by administering a range of doses of the agent to set of trangenic animals having human CD20, determining at least one dose that results in a decrease in cells bearing human CD20.

The transgenic animals of the present invention, including cells, tissues, or other materials derived therefrom, can be utilized as models for diseases, especially diseases associated or mediated by CD20 bearing cells. Animals of any species, including, but not limited to, mice, rats, rabbits, guinea pigs, pigs, micro-pigs, goats, and non-human primates, e.g., baboons, monkeys, and chimpanzees may be used to generate disease animal models. These systems may be used in a variety of applications. Such assays may be utilized as part of screening strategies designed to identify agents, such as compounds that are capable of ameliorating disease

symptoms. Thus, the animal- and cell-based models may be used to identify drugs, pharmaceuticals, therapies and interventions that may be effective in treating disease.

　　　　　Cell-based systems may be used to identify compounds that may act to
5　　ameliorate disease symptoms. For example, such cell systems may be exposed to a compound suspected of exhibiting an ability to ameliorate disease symptoms, at a sufficient concentration and for a time sufficient to elicit such an amelioration of disease symptoms in the exposed cells. After exposure, the cells are examined to determine whether one or more of the disease cellular phenotypes has been altered to
10　　resemble a more normal or more wild-type, non-disease phenotype.

　　　　　Other uses will be readily apparent to one of skill in the art.

　　　　　The following non-limiting examples are illustrative of the present invention.


## EXAMPLES

15
### Example 1

　　　　　This example describes generation of human CD20 BAC transgenic (Tg+) mice and a study of the effects of anti-human CD20 antibody treatment in the hCD20+ mice.

　　　　　Human CD20 transgenic mice were generated using CITB Human BAC-D-
20　　Clone No. 117H19 from Invitrogen. (Invitrogen, Carlsbad, CA)  DNA encoding human CD20 was isolated from human lymphocytes and was sent to Invitrogen. Invitrogen tested the DNA against the filters with the clones from the human BAC library and identified clone 117H19. Previous attempts to generate transgenic mice expressing human CD20 were not successful, possibly due in part to the failure to
25　　include sufficient transcriptional control regions in the transgene construct. Transgenic mice were generated by micro injecting a human CD20 BAC construct prepared with clone 117H19 into a fertilized egg of FVB inbred strain of mice. The fertilized eggs were incubated for 1-7 days and then were implanted into surrogate mice. Mice were screened based on the FACS analysis of human CD20 expression.
30　　As can be seen from the FACS plots in Figure 1, mice heterozygous (Tg+/-) and homozygous (Tg+/+) for the transgene express human CD20 on their B220+ B cells. The murine CD20 has not intentionally been disrupted.

　　　　　Figure 2 provides a schematic diagram of expression of various cell surface markers (CD43, IgM, IgD) during B cell differentiation and maturation. In the Tg+

mice, hCD20 is expressed on pre-B, immature B cells and mature B cells. Human CD20 is found on the same cell types as that of humans and is expressed on these cell types at a comparable to slightly lower level as on human B cells.

The Tg+ mice were screened for human CD20 expression in the B cells of
5 the bone marrow, spleen, mesenteric LN and Peyer's patches using anti-human CD20 antibodies conjugated to FITC (BD Pharmingen) (results are shown in Figures 3-6). Gating the cells on B220 and CD43, CD21, or CD38 allows delineation into the various populations of B cells from the different tissues. For gating, cells were stained with anti-B220 Ab conjugated to PerCP (BD Biosciences)
10 and with anti-CD43 Ab, anti-CD21 Ab or anti-CD38 Ab conjugated to PE (fluorescence, Becton Dickinson).

The expression levels of human CD20 on peripheral blood cells from a CD20 transgenic mouse were compared to expression of CD20 on human peripheral blood cells. Peripheral blood cells were obtained from a several different human
15 donors and from hCD20Tg+ mice and stained with labeled anti-human CD20 antibody (mH27). The cells were analyzed by FACS and were gated for expression of human CD19 and B220, respectively. A representative graph is shown in Figure 22. The numbers on the graph represent mean fluorescence intensity. The numbers on the graph show that, based on a comparison of mean fluorescent intensity, human
20 CD20 is expressed on transgenic cells at a level about 40% of that of CD20 expressed on human cells.

These results show that B cells obtained from many different tissues in the transgenic mice express human CD20 marker. The human CD20 marker is found predominantly on mature B cells but also can be found on pre-B and immature B
25 cells similar to the profile observed in humans.

The transgenic mice were then treated with anti-human CD20 mAb m2H7 in order to determine if the antibody treatment would result in B cell depletion. The antibody m2H7 can be obtained from BD PharMingen (San Diego, CA), eBioscience, or Calbiochem. The anti-human CD20 activity of m2H7 was
30 compared to that of Rituxan in vitro assays and had comparable activity. A humanized antibody, such as Rituxan, could also be utilized in the cell killing studies because cell killing in vivo occurs over a short enough period of time that an immune response to the humanized antibody is not a concern.

The antibody m2H7 was administered to the transgenic mice as outlined in the schematic in Figure 7 at a dose of 1 mg total which is equivalent to 3.5 mg for a 70 kg person. FACS analyses were done on peripheral blood, spleen, lymph node, bone marrow, and Peyer's Patches at the days indicated by the arrows. Serum levels

5   of anti-CD20 mAb were monitored.

Treatment of Tg+ mice with anti-CD20 mAb (m2H7) alone results in depletion of B cells in peripheral blood, mature peripheral lymph node B cells, T2 and follicular B cells in the spleen (see Figures 8-11). However, it was also observed that certain B cell subsets are resistant to killing by anti-CD20 antibody

10  despite very high, likely saturating levels, of antibody on the cell surface. These resistant B cells are the marginal zone B cells in the spleen (Figure 10), and the germinal center B cells in both the Peyer's patches (Fig. 12) and spleen (Figure 14). In Figure 14, mice were injected with a first dose of anti-CD20 mAb at 100 ug on day 1, followed by a second, 100 ug dose on day 3 (it is likely that a single dose at

15  50 ug was sufficient to saturate the B cells). T2/follicular B cells were depleted but the germinal center B cells from the Peyer's patches were shown to be bound with anti-CD20 mAb but were resistant to killing.

The recovery of B cells following anti-human CD20 antibody treatment was studied. Antibody was administered to the mice at day 1. Figure 13 shows that at

20  day 6 post antibody treatment, B cells in the peripheral blood were not detectable. At week 6, upon clearance of the antibody, hCD20+ cells begin to be detected and by week 14, B cells appeared to have recovered to normal levels. Recovery results from precursor B cells which do not express CD20, which then subsequently develop into mature B cells with human CD20+.

25  Figure 14 shows FACS plots demonstrating resistance of splenic germinal center B cells to short-term (single injection) anti-CD20 mAb treatment. Mice were unimmunized or immunized with sheep red blood cells (SRBC) by intraperitoneal injection at day 1 to induce germinal centers in the spleen. The germinal centers appear by day 7. At day 8, one group of mice was treated with m2H7. The control

30  set of mice was treated with mIgG2a isotype control antibody. Spleen cells from the mice were analyzed at day 12. PNA (peanut agglutinin), which stains for germinal center, was utilized. No detectable germinal center cells were seen in the spleens of mice not immunized with SRBC whereas the spleens of immunized mice show 0.3% PNA staining cells. While T2/Follicular B cells are depleted with anti-CD20

33

antibody treatment, marginal center B cells in the spleen are resistant to the antibody.

Next, it was determined whether upon B cell depletion, the mice were able to develop a T independent immune response. Mice were treated with m2H7 or
5    isotype control antibody mIgG2a at day 0. At days 3-7, B cell depletion has occurred. At day 7, the mice were injected i.v. with Streptococcus Pneumoniae IV to induce a response to the polysaccharide. A T cell independent response was mounted on day 11. The results shown in Figure 15 demonstrated that treatment with anti-human CD20 did not affect the B cell response from the marginal zone and
10   B 1 cells, i.e., the non-depleted MZ and B1 B cells confer protection to T-independent antigens. This data demonstrates that some aspects of humoral immunity, specifically T-independent B cell responses (in this case), are preserved despite treatment with anti-CD20 mAb.

In summary, the human CD20 transgenic animals expressed human CD20 on
15   mature, pre-B and immature B cells in blood, bone marrow, spleen, lymph nodes and Peyer's patches. The expression level of human CD20 on the transgenic cells, as measured using FACS, was about 40% of that of CD20 on human cells. Treatment of the mice with anti-human CD20 antibodies resulted in depletion of B cells within 3-4 days of treatment except for the marginal zone B cells in the spleen (Figure 10),
20   and the germinal center B cells in both the Peyer's patches (Fig. 12) and spleen (Figure 14). Not to be bound by any theory, B cell death appears to be mediated by ADCC, complement dependent cytotoxicity (CDC) or apoptosis or a combination of the three. Responses to a T independent antigen were observed in anti-human CD20 treated mice which is consistent with the resistance of splenic marginal zone
25   B cells to depletion by the anti-human CD20 antibody. The B cells that are resistant to killing with anti-human CD20 antibodies provide for retention of T-independent immune response and/or an indication that combination therapy may be required to deplete all of the B cells, if desired. Recovery of B cells expressing human CD20 was observed by 14 weeks after treatment with anti-human CD20 antibodies, most
30   likely due to the maturation of precursor B cells. These results are similar to those seen in humans treated with Rituxan.

## Example 2

This example demonstrates the synergy between anti-CD20 mAb and BR3 antagonist treatments for B cell modulation/depletion. BR3-Fc is an immunoadhesin having the extracellular domain of human BR3 fused to constant domain of an immunoglobulin sequence in this case, human IgG1.

Human CD20 transgenic mice expressing (designated as hCD20$^+$ mice) were treated with intraperitoneal injections of anti-CD20 mAb (single injection of 100 micrograms on day 9), BR3-Fc (100 micrograms every other day from days 1 through 12), or the combination of anti-CD20 mAb and BR3-Fc. Each group consisted of 4 mice. Two days following the last injection, the mice were sacrificed and analyzed for hCD20$^+$ B cells. FACS analysis of spleen, blood, lymph node and Peyer's Patches were analyzed for B cell markers (CD21$^+$CD23$^+$).

The results indicate that anti-CD20 mAb therapy depleted >99% of the mature circulating B cells in the blood and lymph nodes and BR3-Fc treatment decreased mature circulating B cells in the blood and lymph nodes (Figure 16). Anti-CD20 mAb therapy depleted T2 and follicular B cells, but not marginal zone B cells in the spleen, whereas BR3-Fc treatment decreased T2/follicular and marginal zone B cells in the spleen.

The combination of anti-CD20 mAb and BR3-Fc synergized to deplete all populations of B cells in the spleen. Anti-CD20 mAb depletion spared most of the marginal zone and some follicular/T2 splenic B cells, while BR3-Fc depletion occurred predominantly in the marginal zone and some follicular/T2 B cells (Figure 16). Thus, the combination of both reagents completely depletes B lineage cells in the spleen. Neither BR3-Fc nor 2H7 nor the combination of the two had an effect on germinal center B cells in Peyer's Patches (Figure 17). Plasma cells were not significantly affected following anti-CD20 mAb treatment (Figure 18), indicating that some aspects of immune responsiveness were maintained in mice treated with anti-CD20 antibody.

These results show that the combination therapy was effective to deplete most of the B cells. Similar to humans, some B cells in transgenic mice are resistant to killing with anti-CD20 antibodies. The combination therapy provide for depletion of the B cells in the spleen resistant to anti-CD20 antibodies. This shows the transgenic mice are also useful to identify combinations of agents that may be more effective in situations that have anti-CD20 resistant cells or very aggressive tumors.

## Example 3

In this experiment, it was demonstrated that natural killer cells play a role in anti-CD20 mAb mediated B cell depletion.

Hybridoma clone, which produces PK-136 mAb (specific against mouse NK1.1), was obtained from ATCC. Four groups of human CD20 transgenic mice were injected ip with control mAb, PK-136, anti-CD20 mAb and the combination of PK-136/anti-CD20, respectively. Doses of ip were as follows:

control mAb:      200ug/ip, 3 ip/week, for 1 week

PK-136:            200ug/ip, 3 ip/week, for 1 week

anti-CD20 mAb:   10 ug/ip, single dose

Lymphocytes from peripheral blood, lymph nodes and spleen were analyzed 3 days after anti-CD20 mAb ip. Data is expressed as mean+/-standard error, with n=8.

The results indicated that treatment with PK-136 resulted in an approximately 80% to 90% reduction in NK cell population among the tissues examined (liver, spleen and blood) (Figure 19). In the absence of majority of NK cells, 2H7 mediated B cell depletion is less efficient(Figure 20). Thus, NK cells play a role in anti-CD20 mAb mediated B cell depletion.

All publications (including patents and patent applications) cited herein are hereby incorporated in their entirety by reference.

What is claimed is:

1.    A non-human transgenic animal whose genome comprises a nucleotide sequence encoding human CD20.

2.    The transgenic animal of claim 1 wherein said nucleotide sequence is operably linked to a human endogenous promoter.

3.    The transgenic animal of claim 2 whose cells express human CD20.

4.    The transgenic animal of claim 3 wherein human CD20 is expressed on the surface of B lymphocytes.

5.    The transgenic animal of claim 3 wherein human CD20 is expressed on the B lymphocytes at a level sufficient for anti- human CD20 antibody bound to the expressing cells to affect killing of the cells, resulting in B cell depletion.

6.    The transgenic animal of claim 1 wherein the genome of said animal contains a disruption in an endogenous gene encoding a CD20 molecule substantially homologous to human CD20.

7.    The transgenic animal of claim 6, wherein the endogenous gene encodes a murine CD20.

8.    A method of identifying an agent capable of treating a B cell lymphoma said method comprising:
    a)    measuring the level of B lymphocytes expressing human CD20 in an animal of claims 1 or 6;
    b)    administering said agent to the animal of claims 1 or 6; and
    c)    measuring the level of B lymphocytes expressing human CD20 in the animal;
        wherein a decrease in the number of B lymphocytes expressing human CD20 in the animal after treatment with the agent identifies the agent capable of treating a B cell lymphoma.

37

9. An agent identified according to claim 8.

10. A method of identifying an agent capable of depleting or killing cells expressing human CD20 said method comprising:

a) measuring the level of B lymphocytes expressing human CD20 in an animal of claims 1 or 6 ;

b) administering said agent to the animal of claims 1 or 6; and

c) measuring the level of B lymphocytes expressing human CD20 in the animal;

wherein a decrease in the number of B lymphocytes expressing human CD20 in the animal identifies the agent as capable of depleting or killing cells expressing CD20.

11. The method of claim 10 wherein said cells are cancer cells.

12. An agent identified according to claim 11.

13. A cell or tissue derived from the transgenic animal of claim 1 or 6.

14. The transgenic animal of claim 1 or 6 wherein said animal is a rodent.

15. The transgenic animal of claim 14 wherein said rodent is a mouse.

16. A method of testing safety of anti- human CD20 therapy, said method comprising:

a) measuring the level of B lymphocytes expressing human CD20 in an animal of claims 1 or 6 ;

b) administering said agent to the animal of claims 1 or 6; and

c) measuring the level of B lymphocytes expressing human CD20 in the animal;

wherein a decrease in the number of B lymphocytes expressing human CD20 in the animal identifies the agent as capable of depleting or killing cells expressing CD20;

d)      monitering the animal for short or long term adverse effects.


17.     A method of testing efficacy of anti- human CD20 therapy,  said
method comprising:

a)      measuring the level of B lymphocytes expressing human CD20 in a
        set of animals of claims 1 or 6 ;

b)      administering to each animal of the set a different dose of an agent;
        and

c)      measuring the level of B lymphocytes expressing human CD20 in the
        animal after each dose;and

d)      determining at least one dose of the agent that results in the most B
        cell depletion.

# Human CD20 Transgene expression in mouse B220+ cells
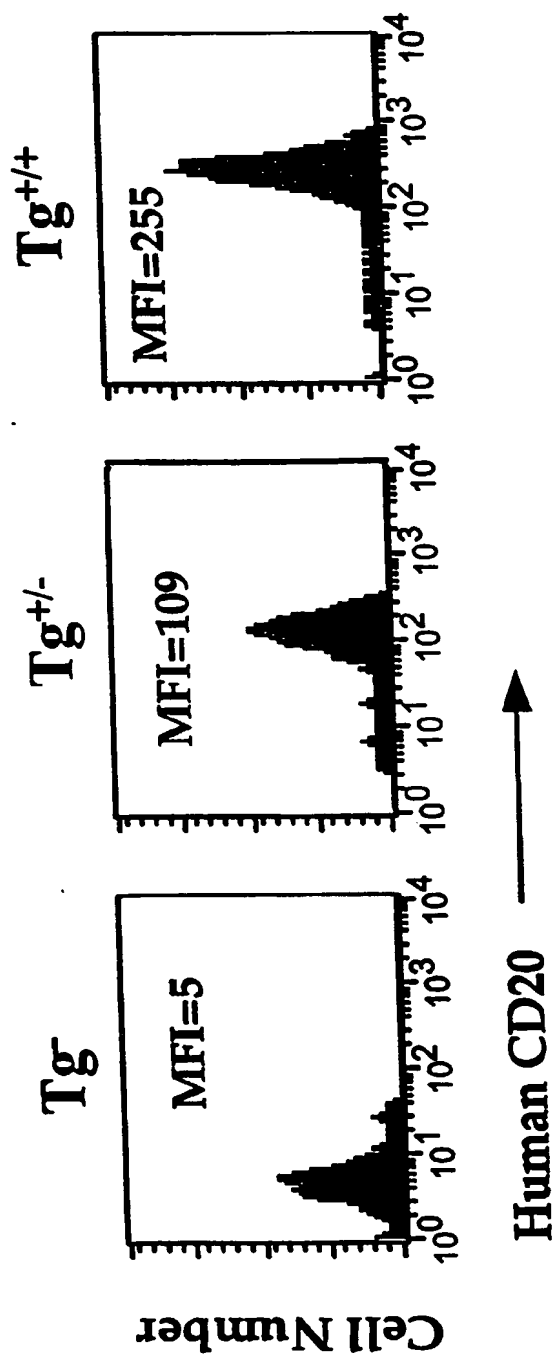


Figure 1

●

●
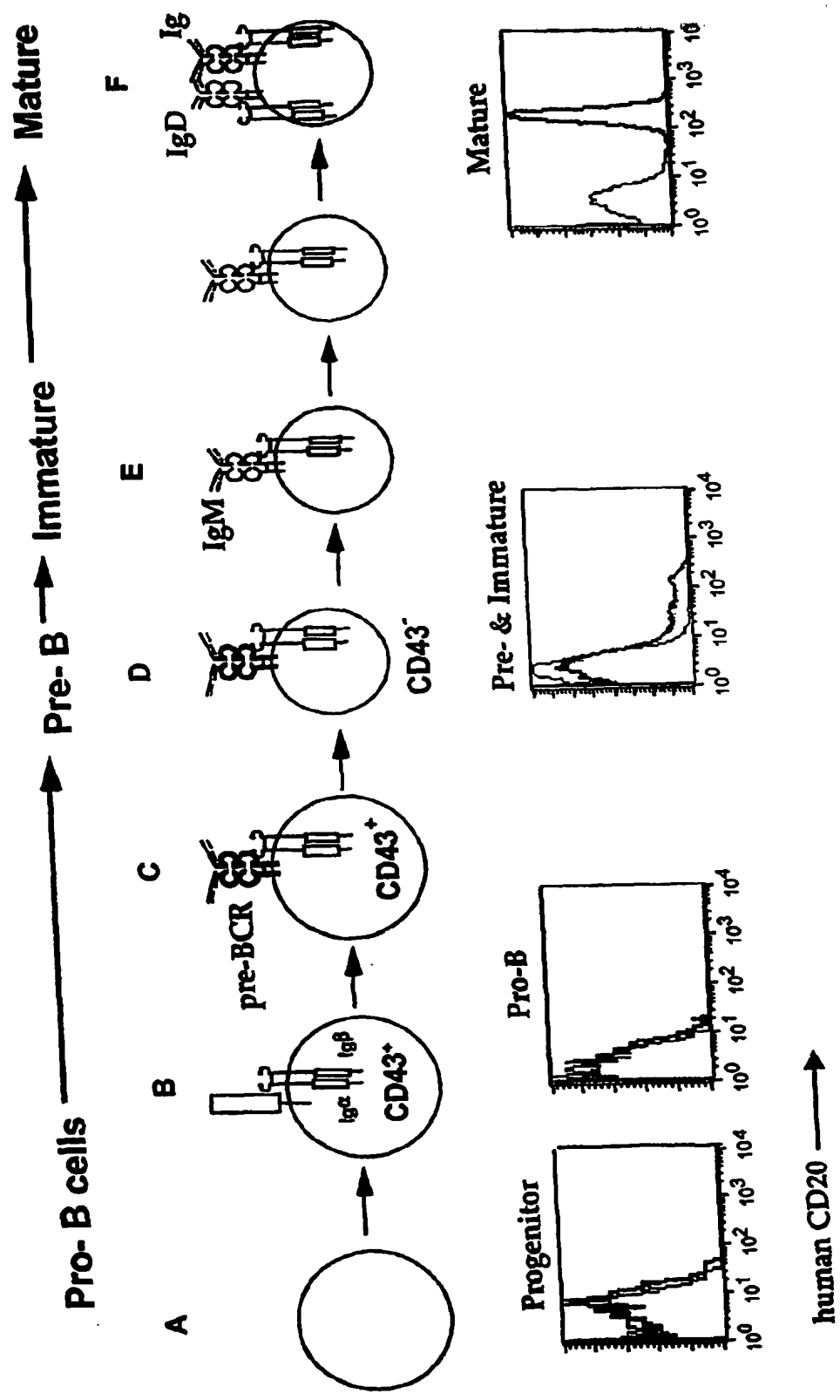
Figure 2

# Expression of human CD20 in Tg⁺ mouse bone marrow
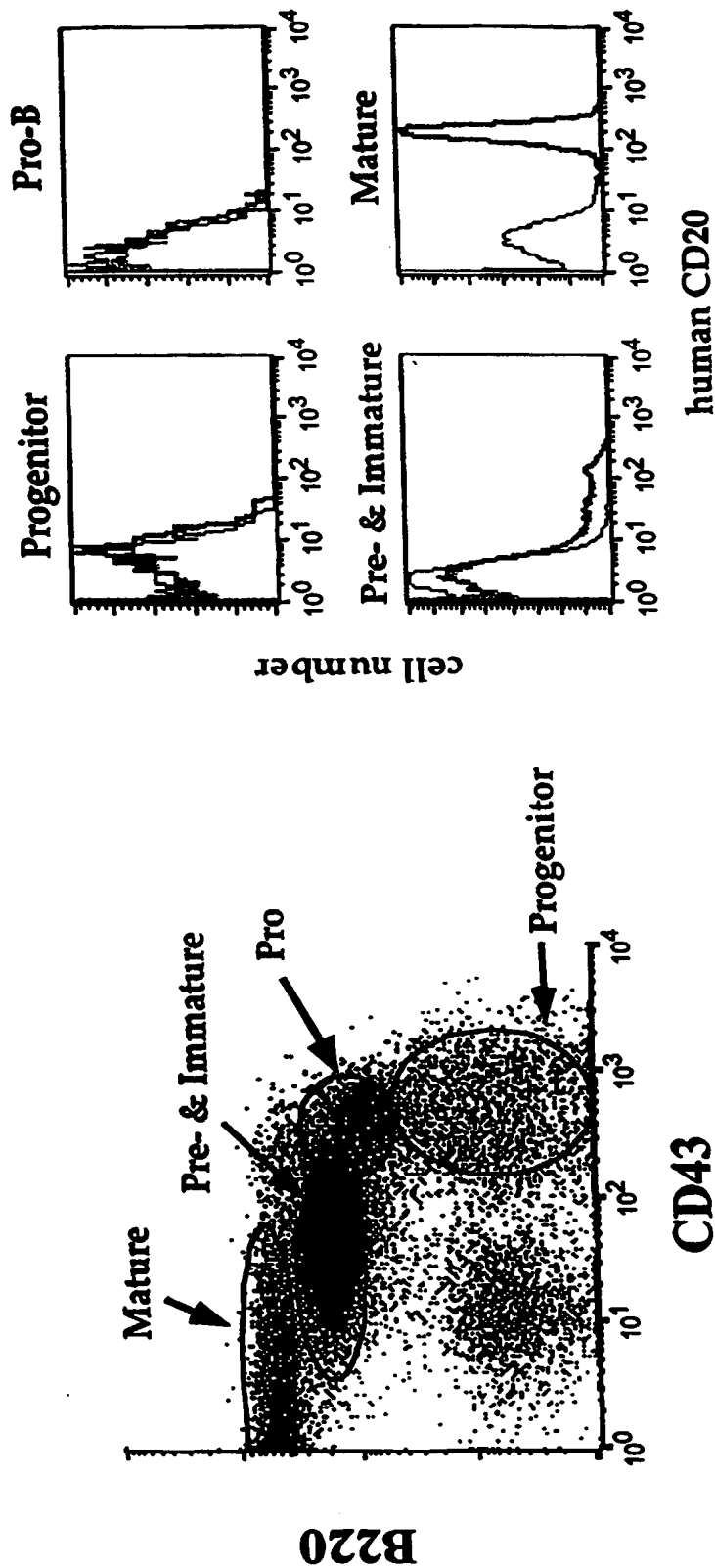


Figure 3

# Expression of human CD20 in Tg⁺ mouse splenic B cells
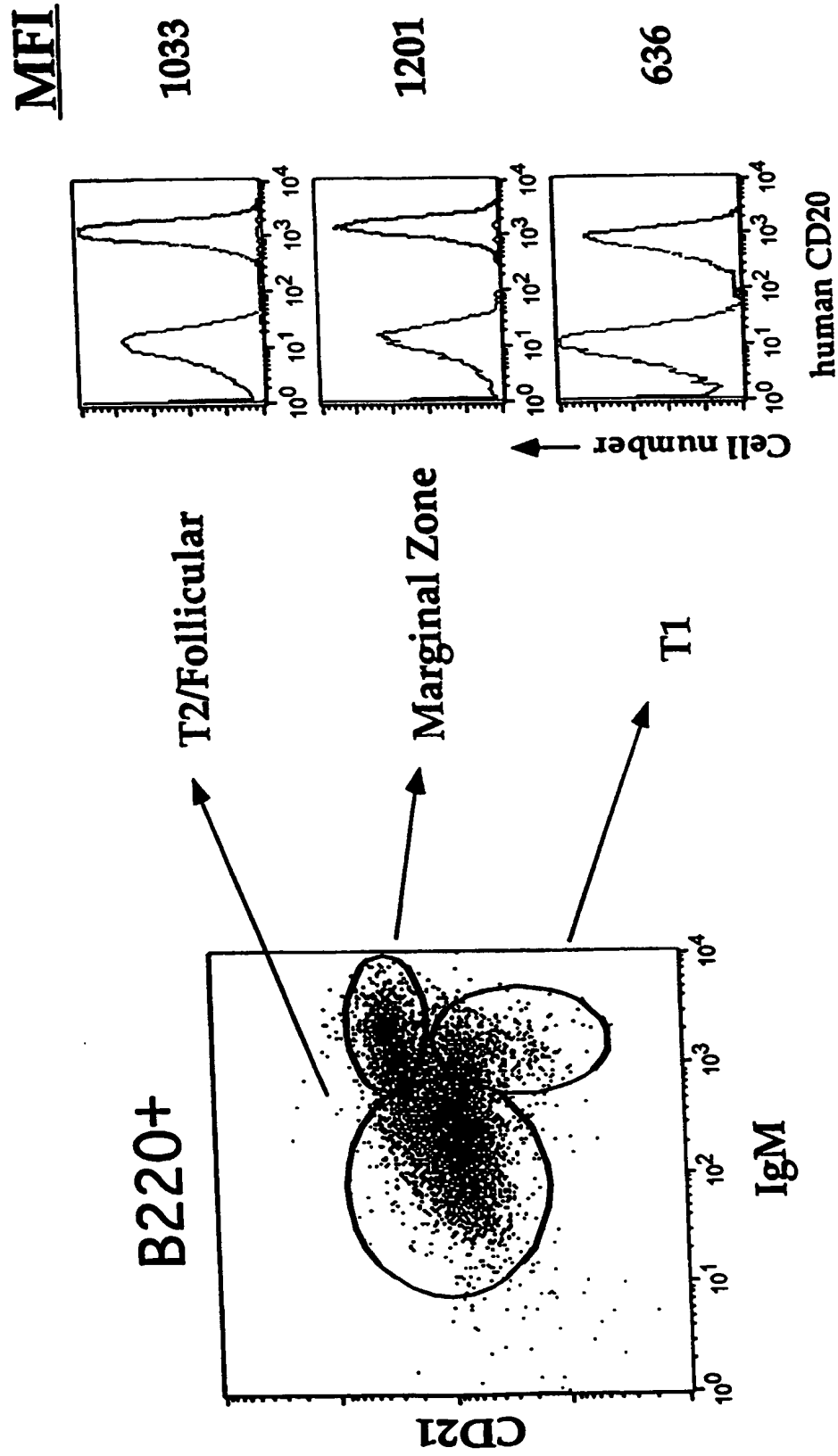


Figure 4

# Expression of human CD20 in Tg⁺ mesenteric LNs
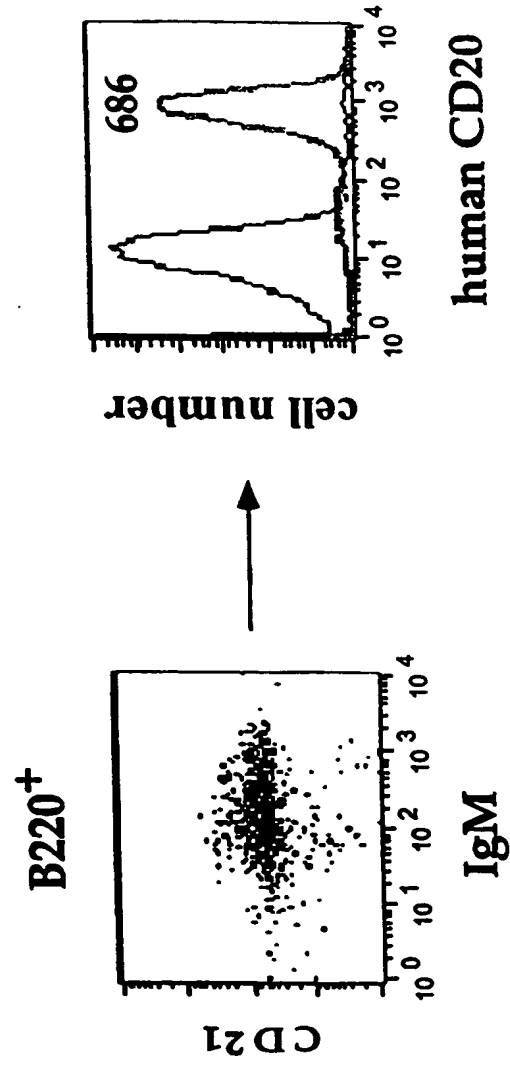


Figure 5

# Expression of human CD20 in Tg⁺ Peyer's Patches

Mature

Germinal Center
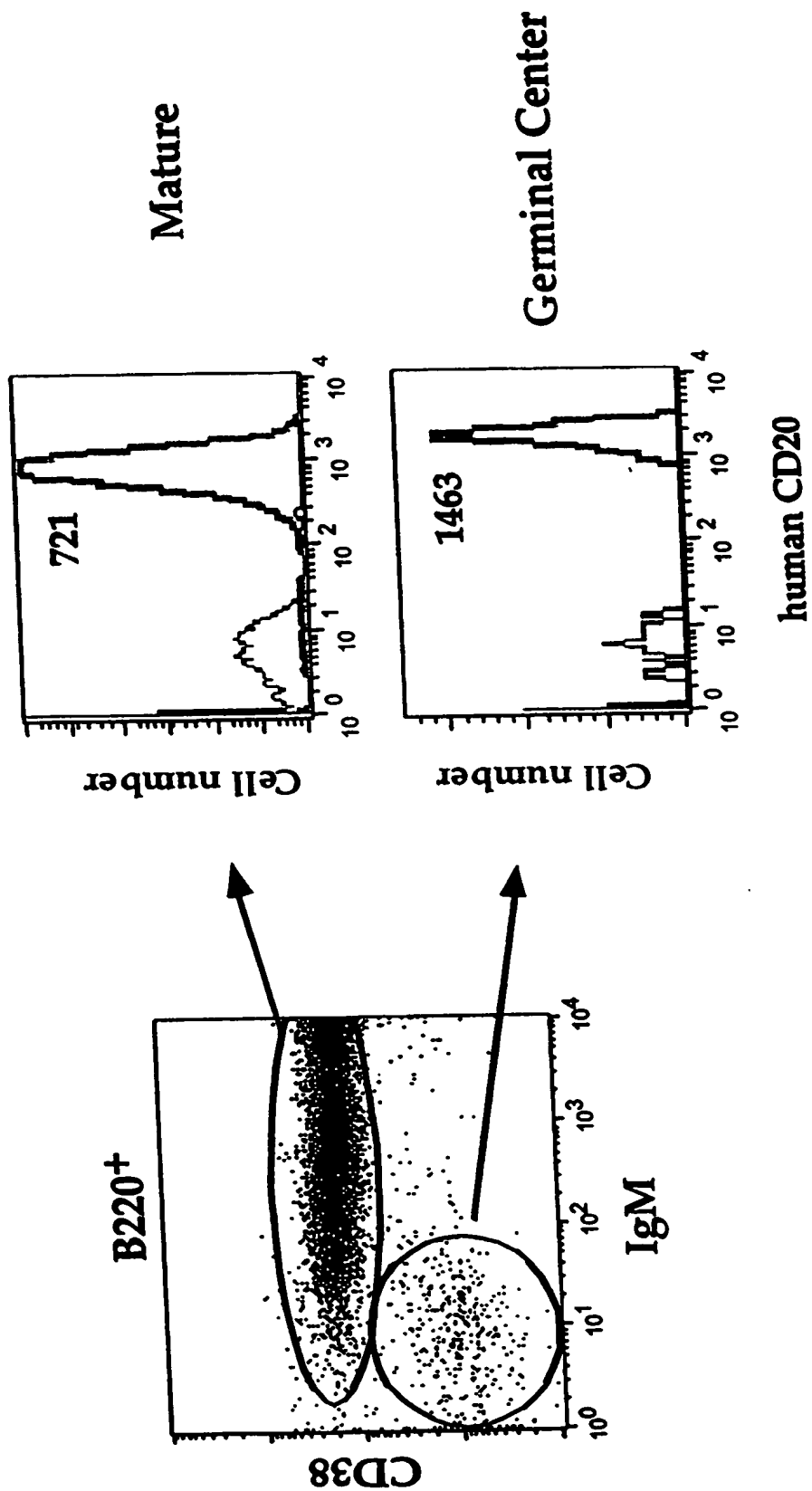


Figure 6

● ●

# Effects of anti-CD20 mAb in mice

1.0 mg anti-CD20 mAb    [=50 mg/kg: 3.5 gm for 70 kg man]

Day  -1  1  2  3  4    7    14    21
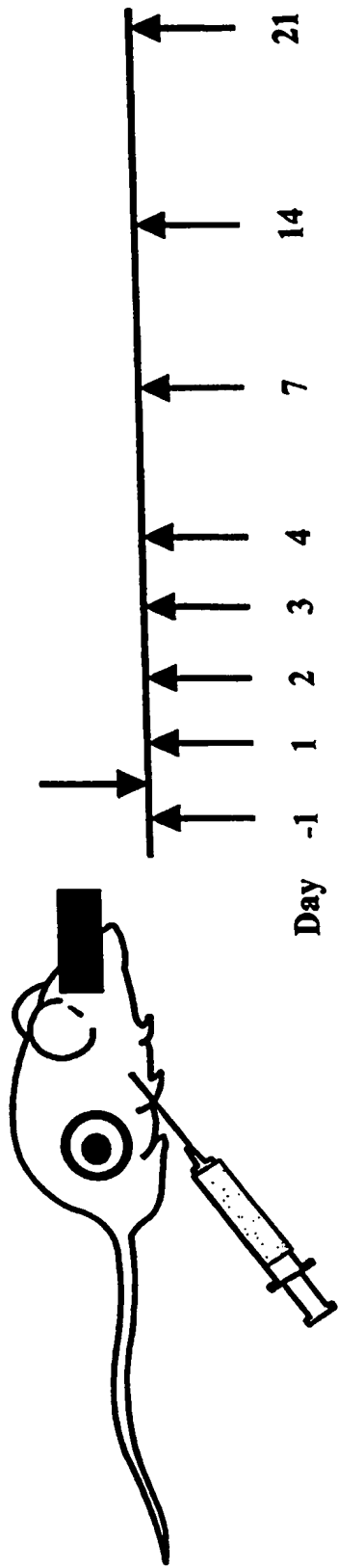
FACS
Peripheral Blood
Spleen
LN
Bone Marrow
Peyer's Patch

Serum levels of anti-CD20 mAb

Figure 7

Depletion of peripheral B cells with anti-CD20 mAbs
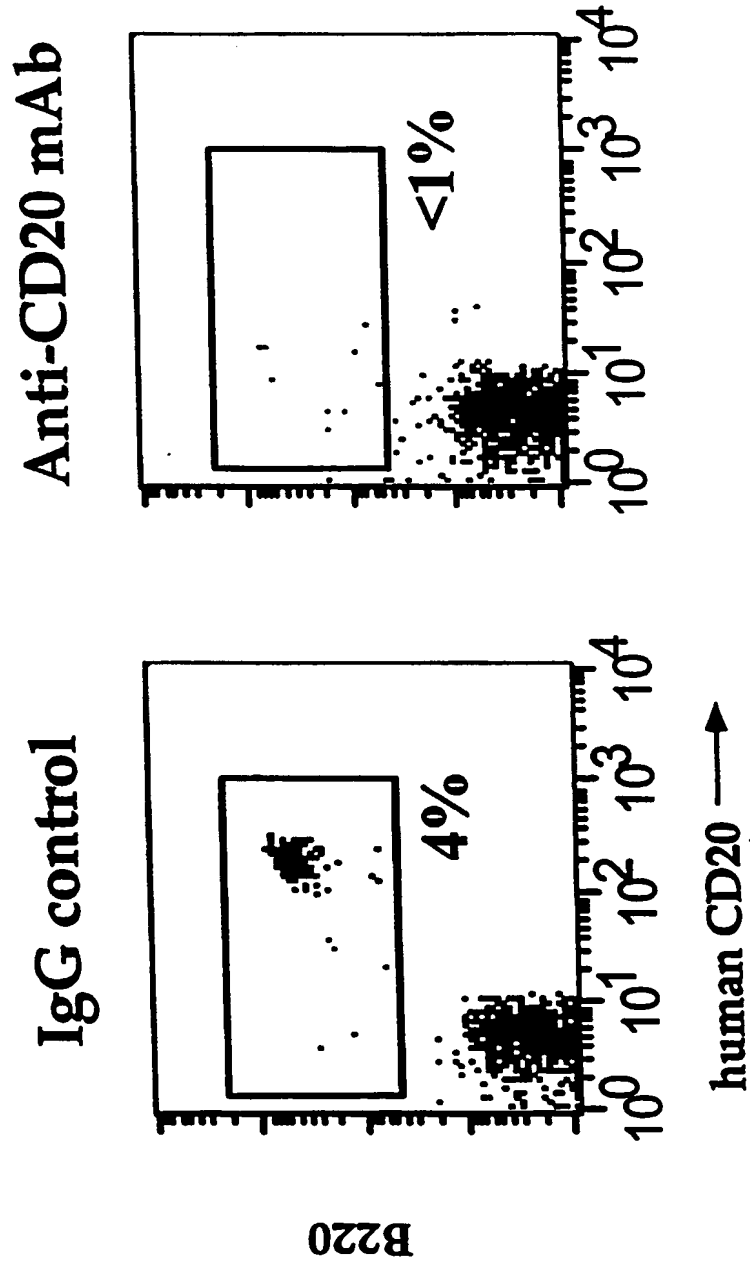
Figure 8

Depletion of mature peripheral LN B cells by anti-CD20 mAb
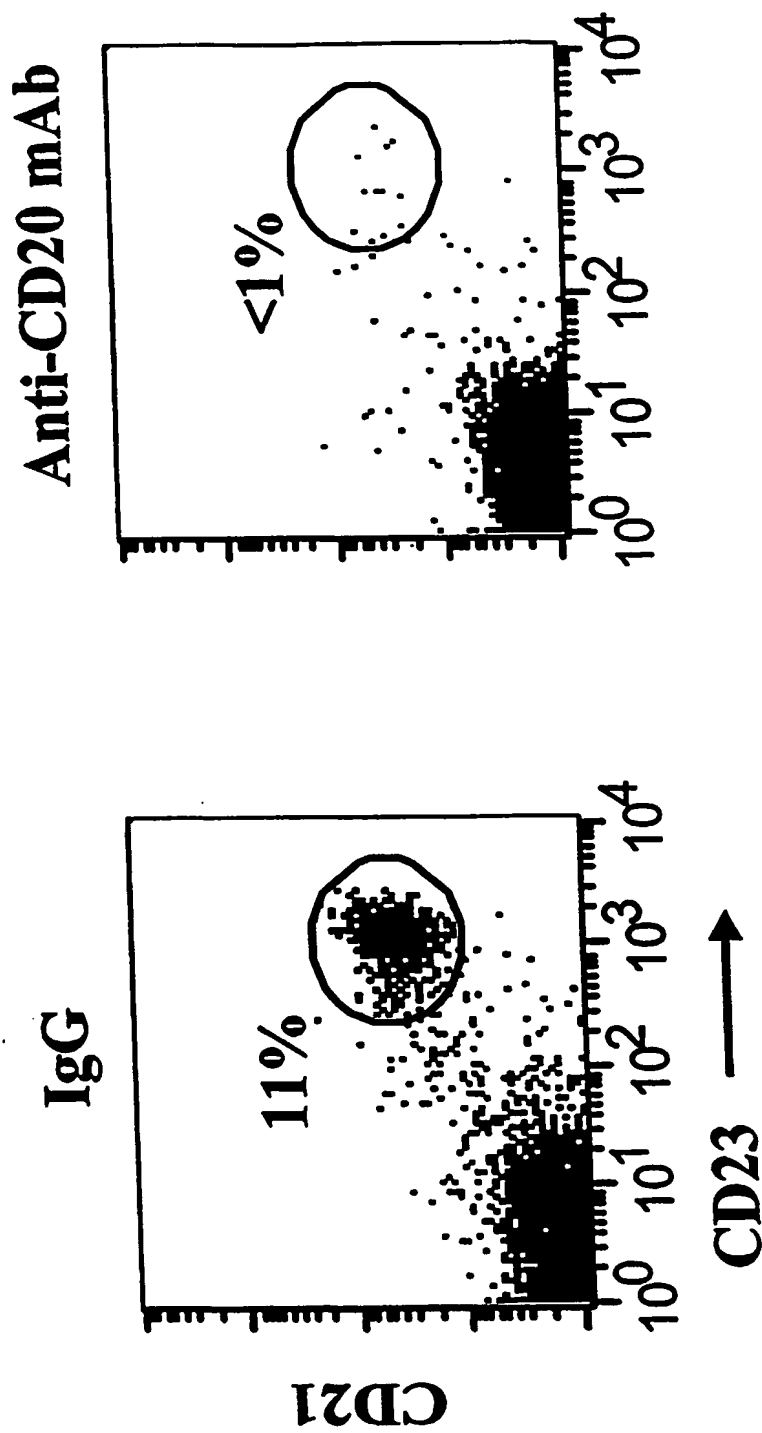
Figure 9

Depletion of splenic T2 B cells by anti-CD20 mAbs
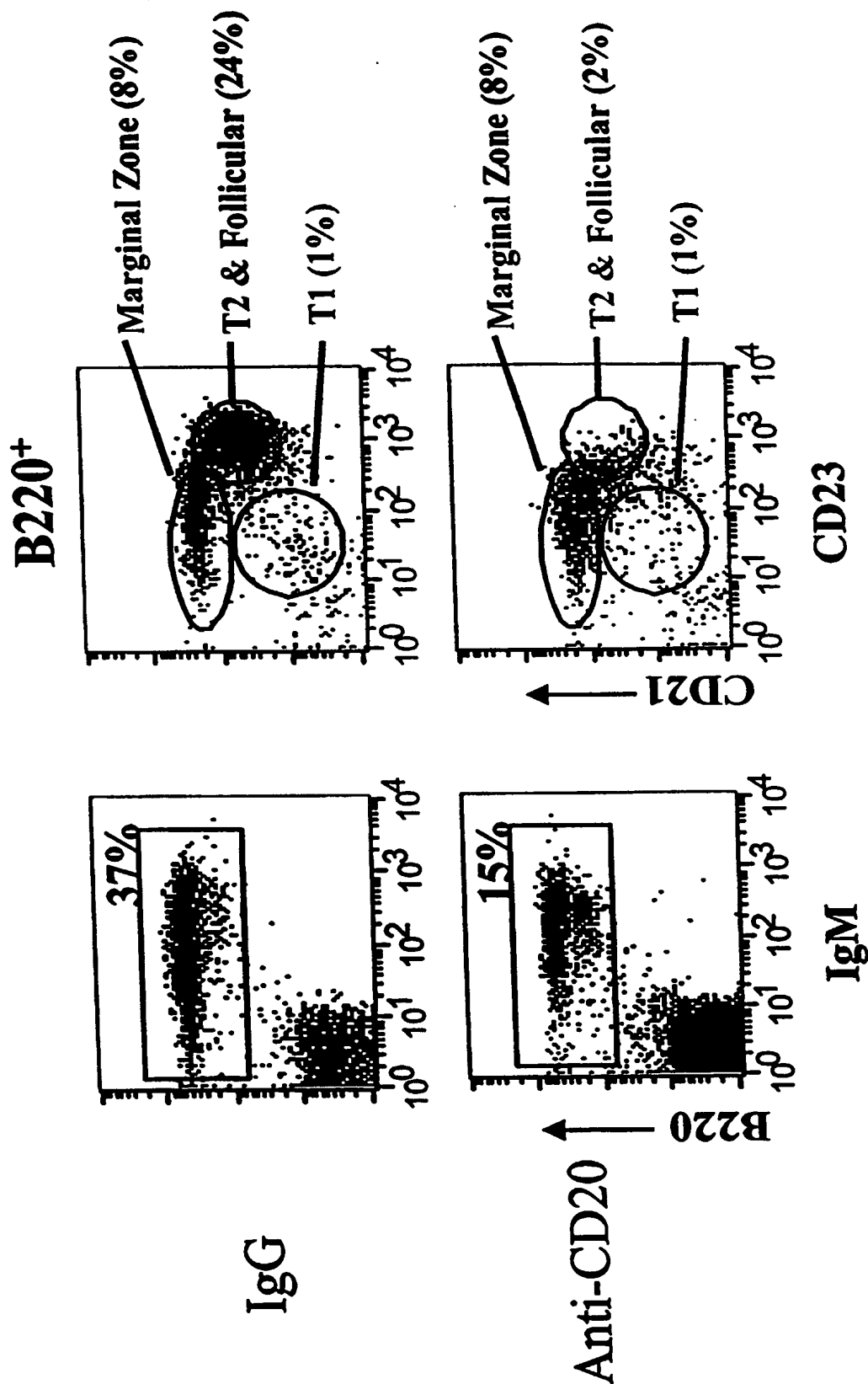
Figure 10

Depletion of re-circulating mature B cells by anti-CD20 mAbs
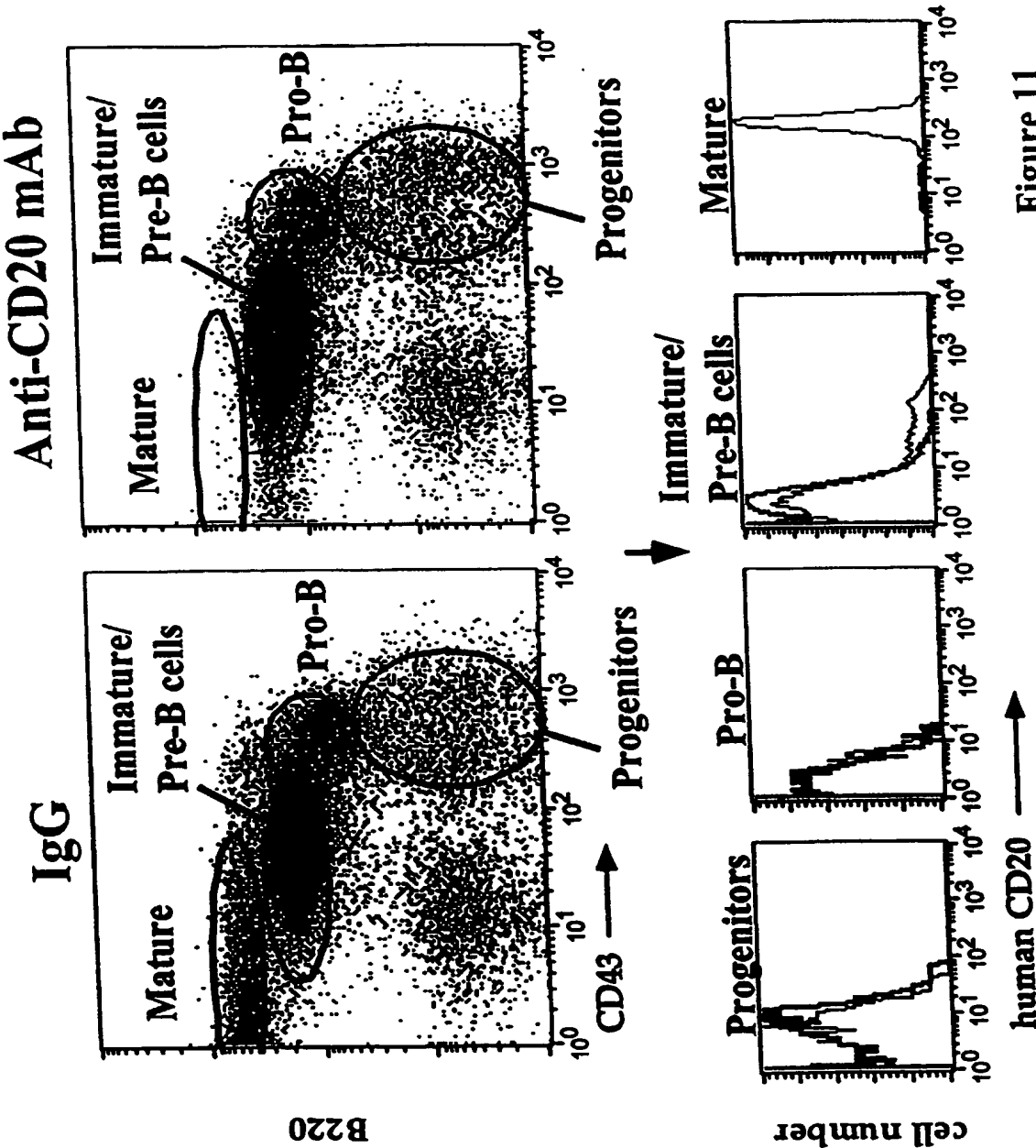
Figure 11

Resistance of Peyer's Patches Germinal Center B cells
to anti-CD20 mAbs

IgG

Anti-CD20 mAb

Mature (32%)

Mature- 4%

Germinal
Center
(3%)

Germinal
Center
(3%)

CD38

hCD20
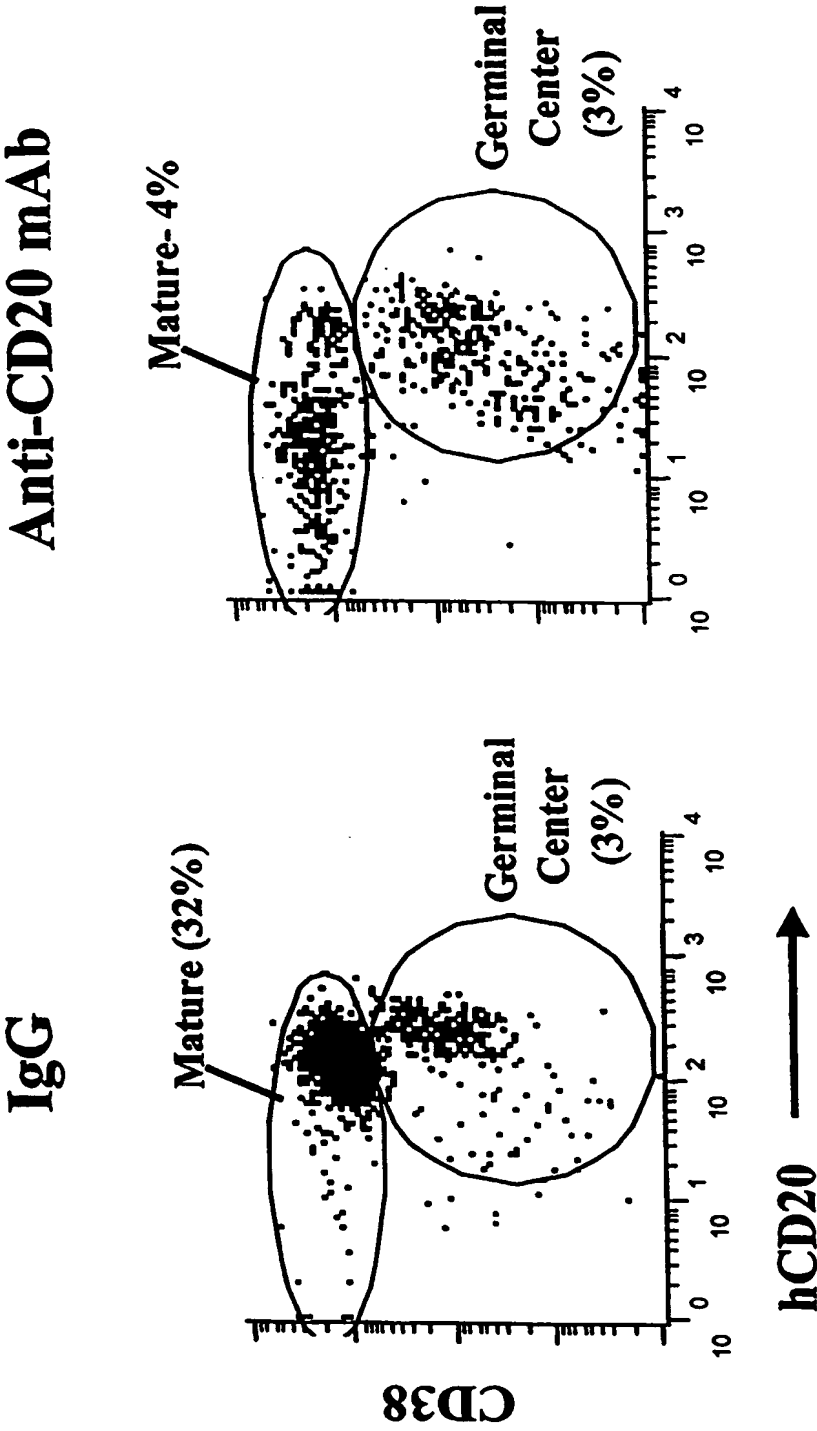
Figure 12

# Depletion & Recovery of B cells following anti-CD20 mAb Rx
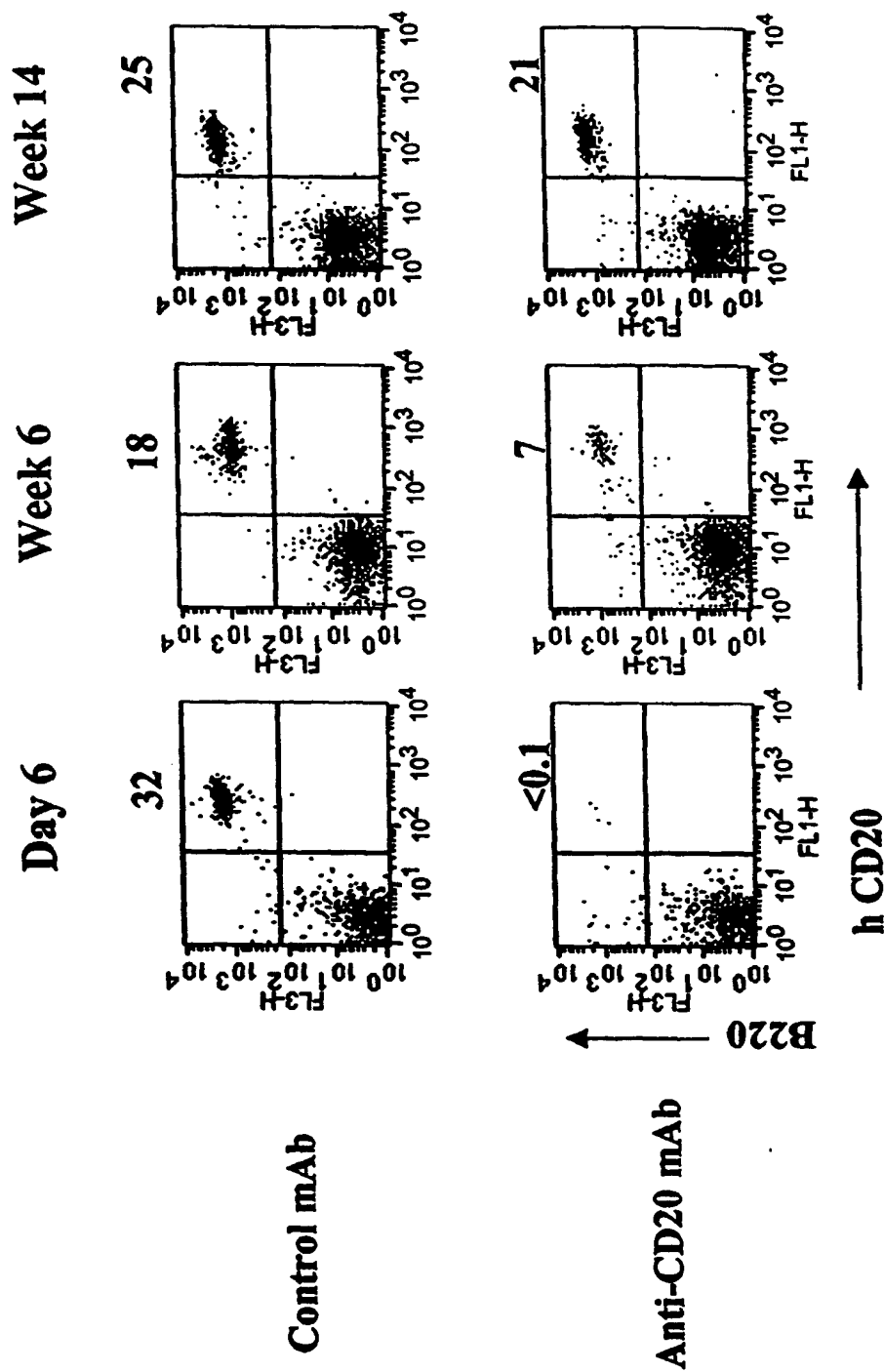


Figure 13

● ●

# Resistance of Splenic Germinal Center B cells to short-term anti-CD20 mAb Rx
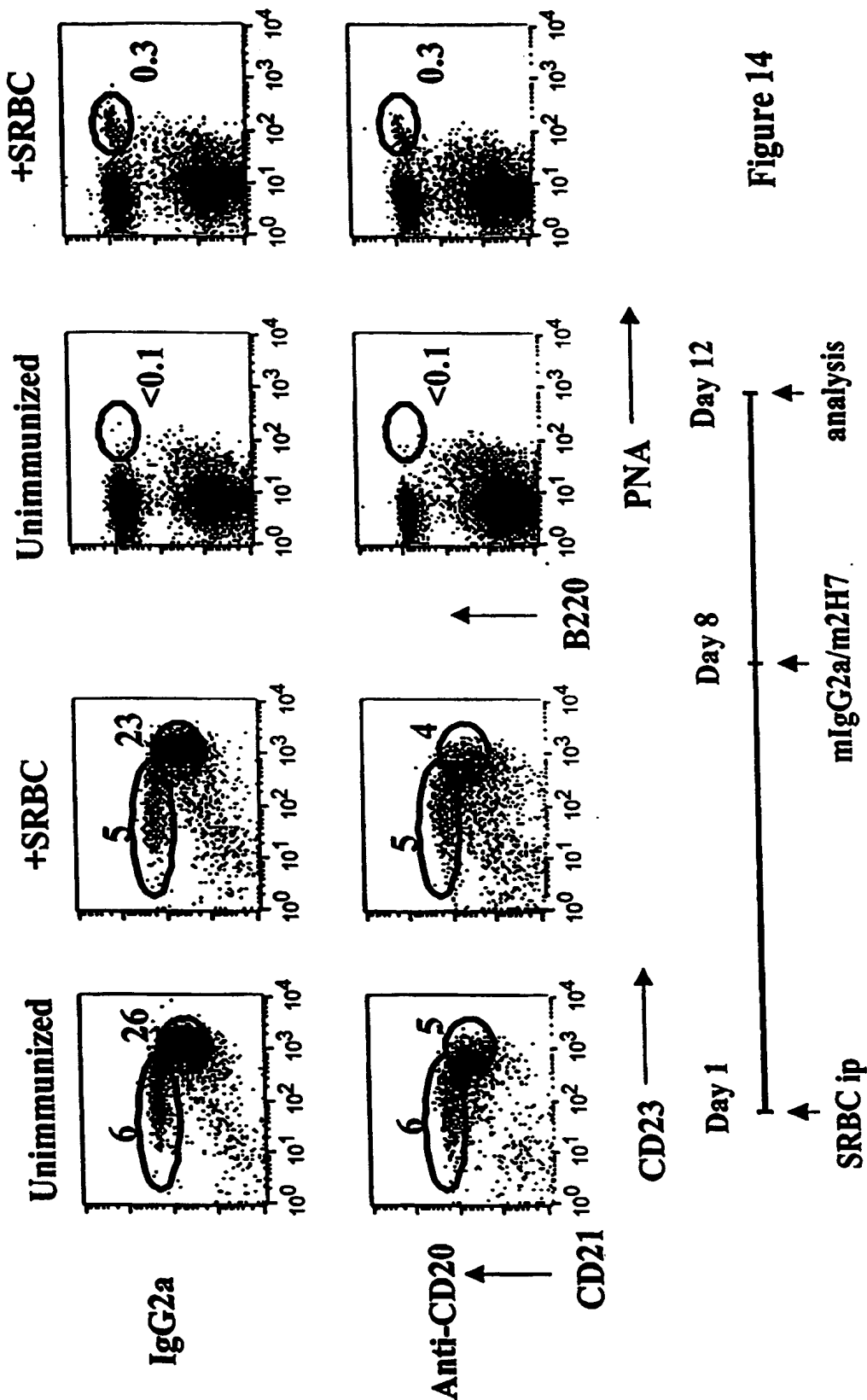


Figure 14

# Non-depleted MZ and B1 B cells confer protection to T-Independent antigens
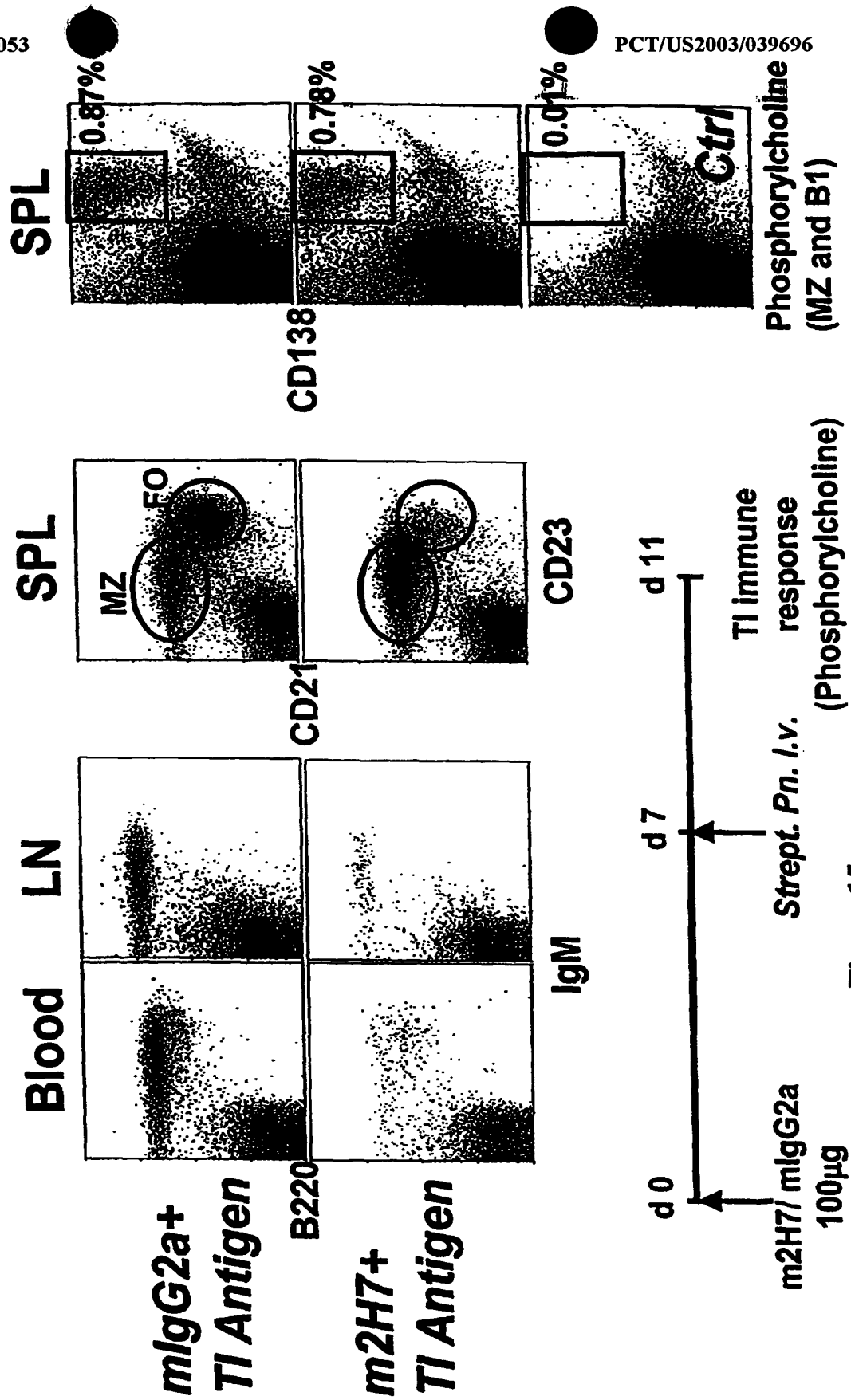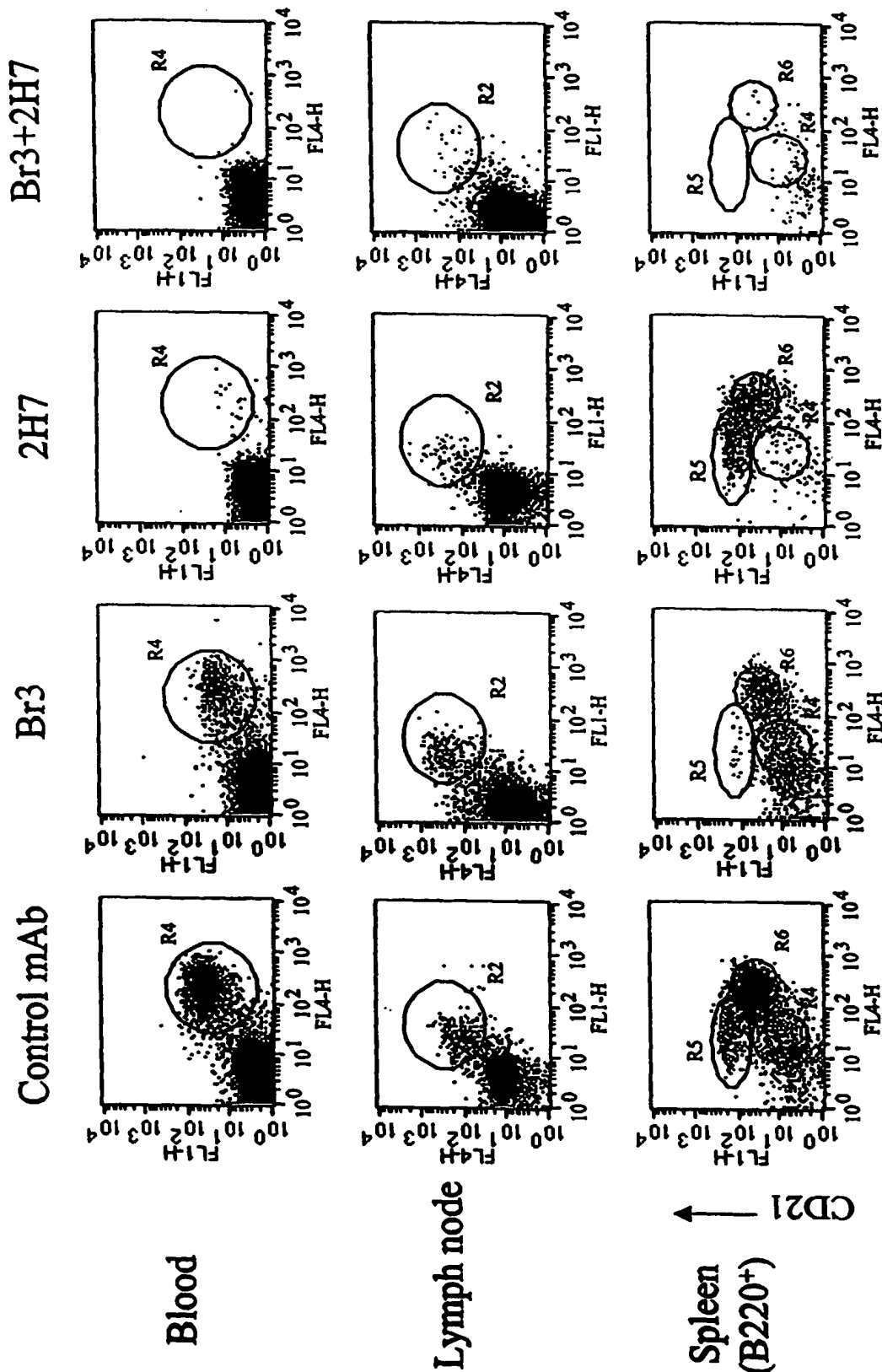


Figure 15

Figure 16

In Peyer's Patches
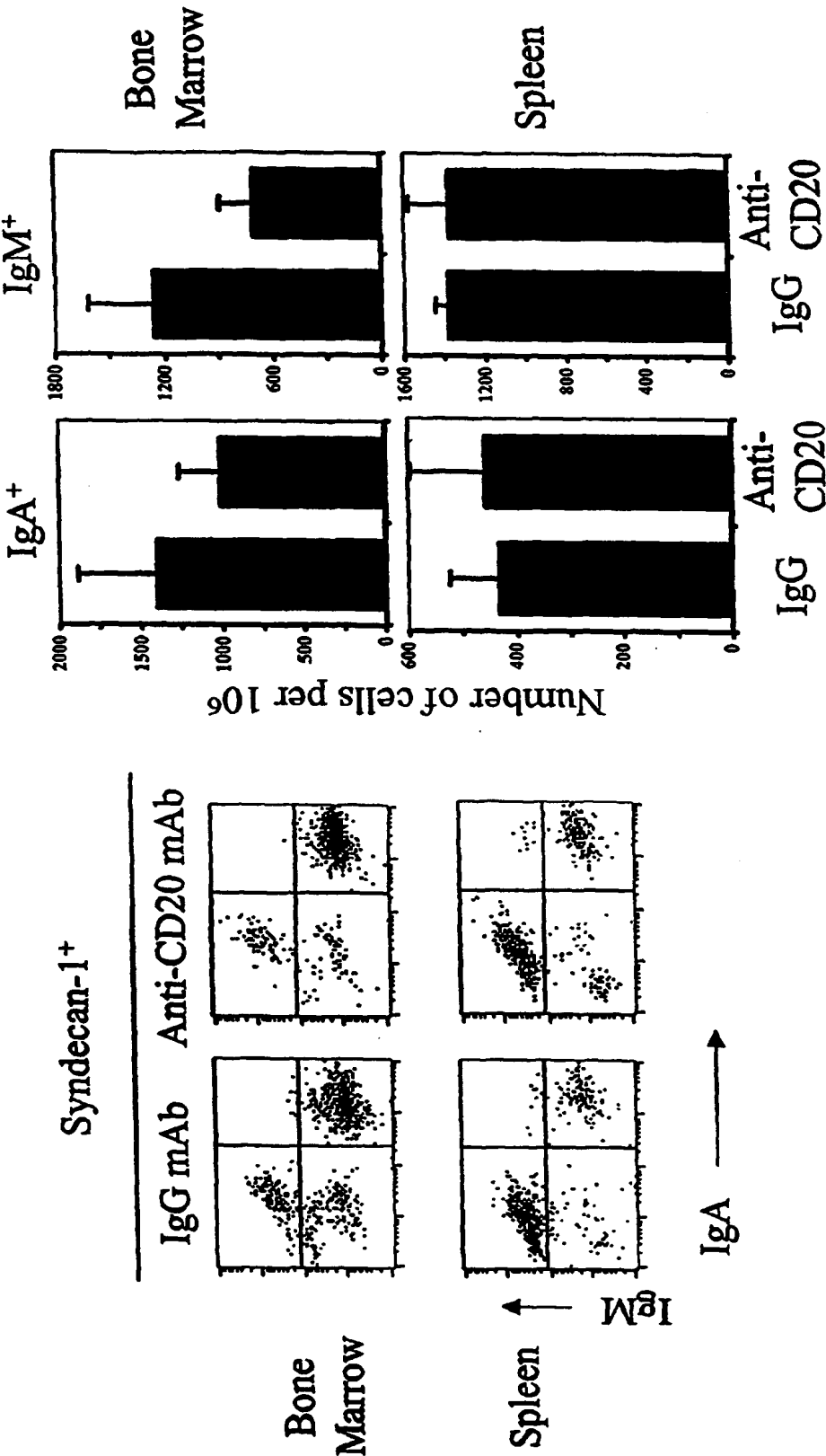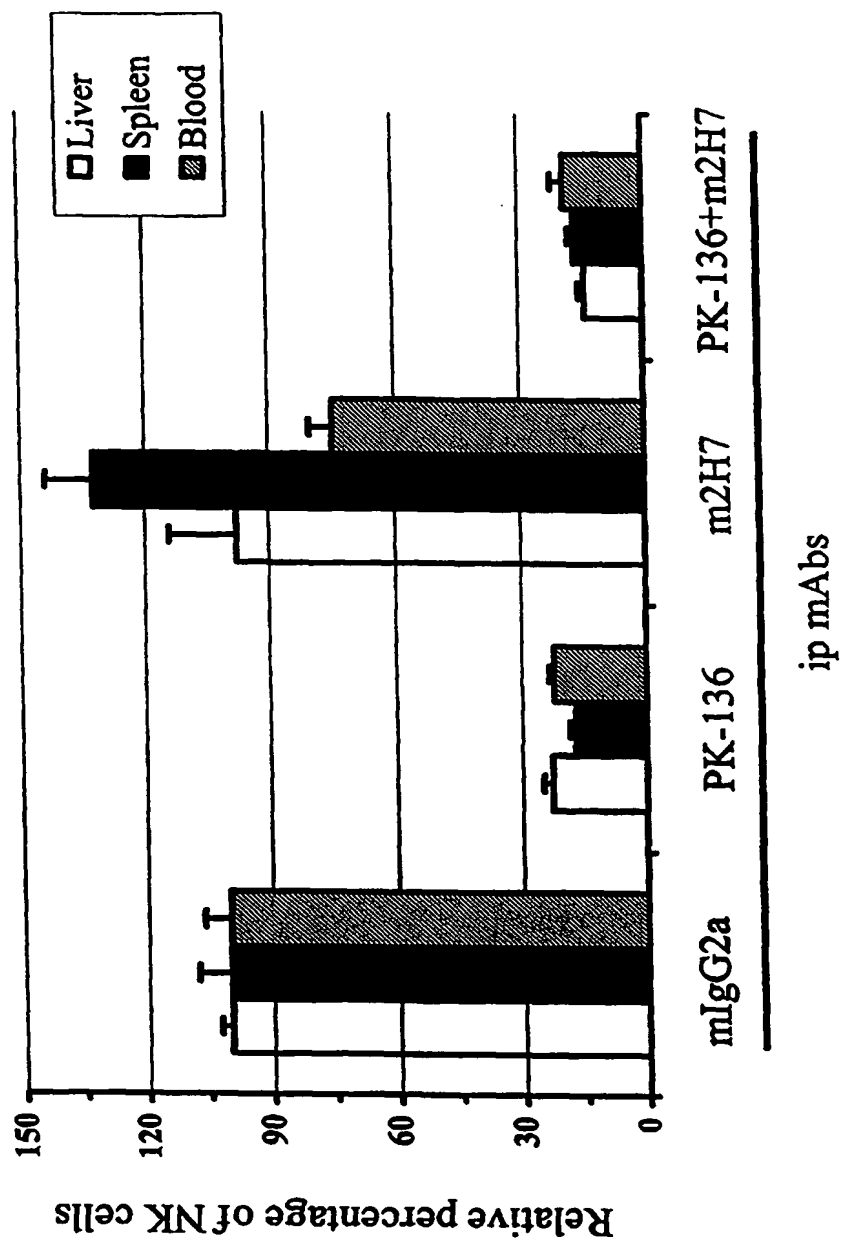
Figure 17

Figure 18

Figure 19

# NK cells play a role in 2H7-mediated B cell depletion
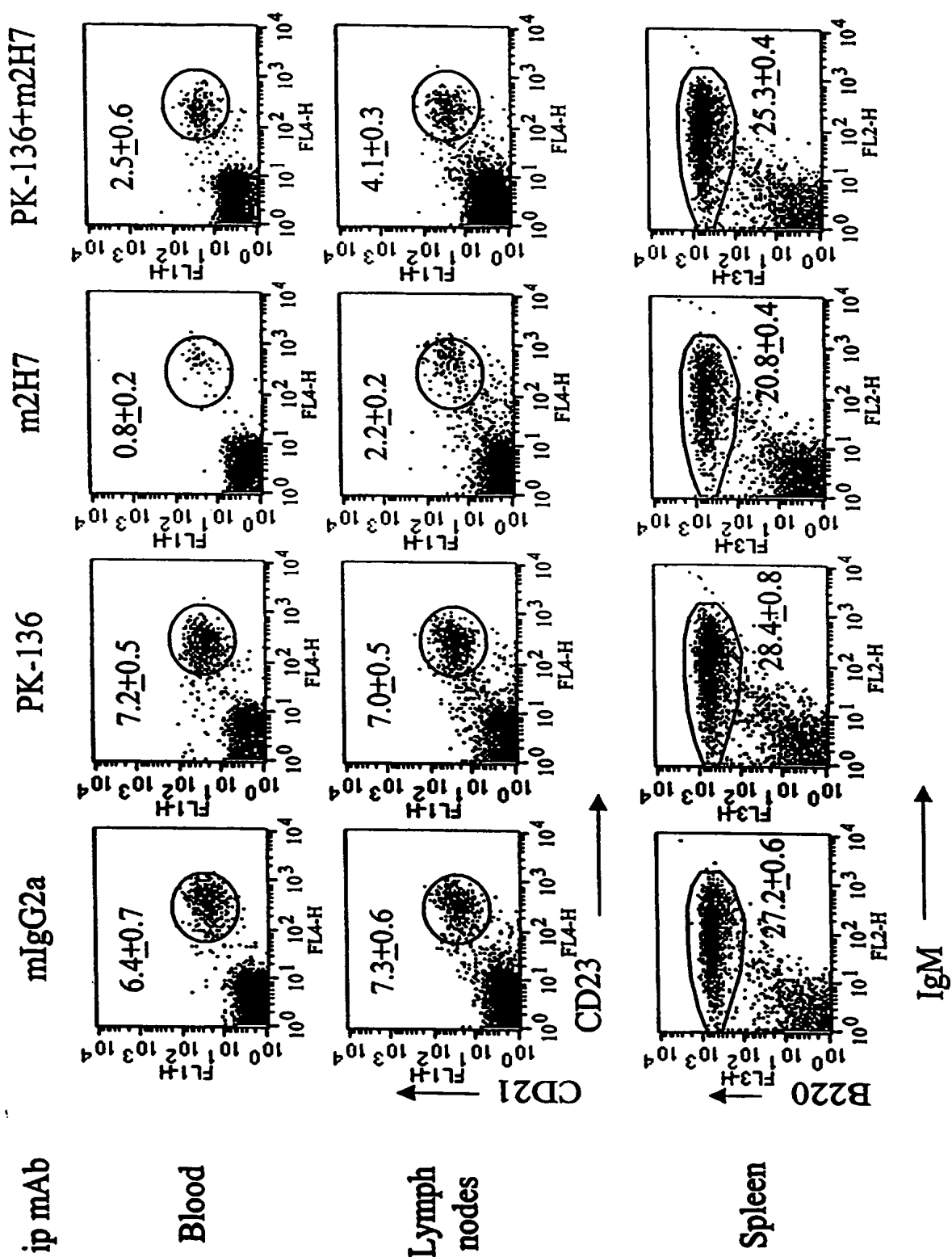


**Figure 20**

# FIGURE 21A

MTTPRNSVNGTFPAEPMKGPIAMQSGPKPLFRRMSSLVGPTQSF
FMRESKTLGAVQIMNGLFHIALGGLLMIPAGIYAPICVTVWYPLWGGIMYIISGSLLA
ATEKNSRKCLVKGKMIMNSLSLFAAISGMILSIMDILNIKISHFLKMESLNFIRAHTP
YINIYNCEPANPSEKNSPSTQYCYSIQSLFLGILSVMLIFAFFQELVIAGIVENEWKR
TCSRPKSNIVLLSAEEKKEQTIEIKEEVVGLTETSSQPKNEEDIEIIPIQEEEEEETE
TNFPEPPQDQESSPIENDSSP"

# FIGURE 21B

```
   1 agtgtgcttg agaaacaaac tgcacccact gaactccgca gctagcatcc aaatcagccc
  61 ttgagatttg aggccttgga gactcaggag ttttgagagc aaaåtgacaa cacccagaaa
 121 ttcagtaaat gggactttcc cggcagagcc aatgaaaggc cctattgcta tgcaatctgg
 181 tccaaaacca ctcttcagga ggatgtcttc actggtgggc cccacgcaaa gcttcttcat
 241 gagggaatct aagactttgg gggctgtcca gattatgaat gggctcttcc acattgccct
 301 gggggggtctt ctgatgatcc cagcagggat ctatgcaccc atctgtgtga ctgtgtggta
 361 ccctctctgg ggaggcatta tgtatattat ttccggatca ctcctggcag caacggagaa
 421 aaactccagg aagtgtttgg tcaaaggaaa aatgataatg aattcattga gcctctttgc
 481 tgccatttct ggaatgattc tttcaatcat ggacatactt aatattaaaa tttcccattt
 541 tttaaaaatg gagagtctga attttattag agctcacaca ccatatatta acatatacaa
 601 ctgtgaacca gctaatccct ctgagaaaaa ctccccatct acccaatact gttacagcat
 661 acaatctctg ttcttgggca ttttgtcagt gatgctgatc tttgccttct tccaggaact
 721 tgtaatagct ggcatcgttg agaatgaatg gaaaagaacg tgctccagac ccaaatctaa
 781 catagttctc ctgtcagcag aagaaaaaaa agaacagact attgaaataa aagaagaagt
 841 ggttgggcta actgaaacat cttcccaacc aaagaatgaa gaagacattg aaattattcc
 901 aatccaagaa gaggaagaag aagaaacaga gacgaacttt ccagaacctc cccaagatca
 961 ggaatcctca ccaatagaaa atgacagctc tccttaagtg atttcttctg ttttctgttt
1021 ccttttttaa acattagtgt tcatagcttc caagagacat gctgactttc atttcttgag
1081 gtactctgca catacgcacc acatctctat ctggcctttg catggagtga ccatagctcc
1141 ttctctctta cattgaatgt agagaatgta gccattgtag cagcttgtgt tgtcacgctt
1201 cttcttttga gcaactttct tacactgaag aaaggcagaa tgagtgcttc agaatgtgat
1261 ttcctactaa cctgttcctt ggataggctt tttagtatag tatttttttt ttgtcatttt
1321 ctccatcagc aaccagggag actgcacctg atggaaaaga tatatgactg cttcatgaca
1381 ttcctaaact atcttttttt tattccacat ttattacgttttt ggtggagtcc cttttgcatc
1441 attgtttttaa ggatgataaa aaaaaaaaaa aaa
```

Figure 21C

```
   1 tgttaaacca aagtaattgg agcgaagccc agggtagcag aagctactga tttcctgtca

  61 cctgatgtct atcagcgatt tcatcttcag gcctggacta caccactcac cctcccagtg

 121 tgcttgagaa acaaactgca cccactgaac tccgcagcta gcatccaaat cagcccttga

 181 gatttgaggc cttggagact caggtaagga atcaatttgc tttctttaaa tgacttaaag

 241 gaggtgatgg ataaggtata gaatggtttt gaagactgga ggttcttgat cttaattcta

 301 gagtttccct agtcagactt cctaatagtt ctatgactta aggaggggtg acgatatcaa

 361 ggcttgctgc ccactcactc ctctaatcag tctccctctc aacaattacc ctatgcagtc

 421 aactgtgaat cattccacaa aagtagtaga ttgcagcata tatattaaat catggtttct

 481 aaaccattgg gttcgaactg gagctctacc actaacaaac aatataacct tgggcaaatt

 541 actaacctct aagcctcagc ttcctcatcg ttaacttatt tatgtcttac atctcagaga

 601 ggggtactgt tctaacttta cagaaggata aaatcgaaac taatgctcag caaagtacaa

 661 agaacaagaa tagcaacaaa aataactatt tattccaaca tgggttcttt gcatacattt

 721 atttcttcaa taatatttat taagaagtaa ctaaatccaa aaattatttt agatcctgaa

 781 caagagagaa caaaatctct actttgatgg aacttccatt ctgtggggaa gagactgaca

 841 ataagcaatt aaataaataa ggtaatttcc tacagtgatc aatgccgtaa agcaattaag

 901 ataggatttt gtaaaagaca gcaaatagga gtacatgtta tagattgagg gttcaaggta

 961 ggctcctcta ggagctgaca tttgagctac acctgaacaa aaagacacta gccatgcaca

1021 gaccatgagc ccagttaagt gttatagcag cccacgagat aagaattatt attatttcaa

1081 ttttacagtt gaacctgagg cccagagaat ttaaagaact tgcccaacat ctcagaacaa

1141 atggaggaat cactattgaa acctgggcaa tctgactcag gaggccacag tcttatatac

1201 tgacattaga aagccttaga gagcctttt tttttctttg agaccgagtc tcactctgtt

1261 acccaggctg gaatgcagtg gcatgatctc agctcactgc aacctctgcc tcctaggttc

1321 aagcaattct cctgccttag cctcccgagt agctgggatt acaggtgcac accaacatgc

1381 ctggctaatt tttgtatttg tagtagagat ggggttttgc catgttagcc agcccggtct

1441 caaactcctg acctcaggtg atctgcccat cttggcctcc caaagtgctt ggattacagg

1501 catgagccac cgtgcccgac ctagagagcc ttcttgatgt gacttgcaca aggtggcaga

1561 gttagagaca gagagaggcc tggaatcgac ccctcctgct tctacagata gtccttacca

1621 tactctgcaa tgttgcctct ggccatcata atgcacaaag gcagataagc aaaaggacaa

1681 ggacaagtcc attgaaaata cattttcaa tattaaagca aaagaaaagc atccaggaat

1741 aagaaacaaa gaggacatgc agtcatatat gcaaggtgtc ctctacaaag ataaagaatg

1801 ccccaaaccc agttgtcaag atcactggca gggactcctg ggcccacatg ctcttcctaa

1861 acaacccctc catctccttt ctcagaactc agcagtaggc cttgcctcag atccaaggtc

1921 actcggaaga ggccatgtct accctcaatg acactcatgg aggaaatgct gagagaagca

1981 ttcagatgca tgacacaagg taagactgcc aaaaatcttg ttcttgctct cctcattttg

2041 ttatttgttt tatttttagg agttttgaga gcaaaatgac aacacccaga aattcagtaa
```

## Figure 21C cont'd

```
2101 atgggacttt cccggcagag ccaatgaaag gccctattgc tatgcaatct ggtccaaaac

2161 cactcttcag gaggatgtct tcactggtgg gccccacgca aagcttcttc atgagggaat

2221 ctaagacttt gggggtaagt cagttgcctt ccatcccatg tcgtagggat tctctggctg

2281 acagaagctg atgcggtata ggtcacatac agaattcaat ccaatttgaa gaattgggat

2341 ccaacctgat gtcttcttta tgtctaacac agtgggccaa atcaggggtg catcagagaa

2401 gttatcactt agatcacctc tgggtgatct tatgtcacct tttggttttg gggcttgtat

2461 atgcaggggt tcccccattc ccagttccat ttgccagaat cccaggcata cctgctccct

2521 ggaaatgccc catgtggttg aggaaacaga ttcgaacaag aaaaagacaa aattcttggc

2581 acctccactg cttcctttag gcattcctca cagctccaag tcaggagcca gagcttccaa

2641 ccttgtcttt gcctgctagc agtgatgatt tcagctcatc cactgctgcc tctgttctct

2701 ccccaggctg tccagattat gaatgggctc ttccacattg ccctgggggg tcttctgatc

2761 atyccagcag ggatctatgc acccatctgt gtgactgtgt ggtaccctct ctggggaggc

2821 attatggtga gtaaaagaat agcagccatt tgggaaatgg tgcagacaaa aatgttaaaa

2881 ggctccacag ggatatgcca gattatttct gtgttgaggg aaatatatga gtaggaaata

2941 ttattgggtt aaagtaatta agaagacagg ttgaccaaat tgagtataaa tcccatggtt

3001 gagagtcagt ggtcctgttt catgtgaatt cagagaaagg ggccctgcat ggatctcaca

3061 gggactgtcc aaagcaagaa ctctccaaag tcagttctgg tggggagggt ggccctagac

3121 atttagacta gatagcaaga tgttttggaa agcaagaggc agcaggaaca tccacttcca

3181 tctacccctt cttgcttaca attctgtttg gttactatgg tacctggtga aacctgtccc

3241 atcacaagtc agtctcattt tgcttatcga cagagcagca ctcttttgac gttttatgta

3301 catgttttcc aaatctgtaa ccctgtctgg gtgtgatttg agttctgtct ctttggtctt

3361 actatattcc tgtcacagat ccccagatga ttgagtaaaa ggcatgaatt tagtgtcact

3421 gagcctgaat aaaggaggaa tatgacagct gaaaaatgaa tacaactgat aaaaatgggt

3481 ggatggttgt gtgaaagttg ctgaaagtgt aggcttcttt ctgaccagtt atcaatgtta

3541 aaaagtgatc tcctctctcc tctatctcct gtcttgccca ccccctctcc atctccccca

3601 cctctctttt ttacagtata ttatttccgg atcactcctg gcagcaacgg agaaaaactc

3661 caggaagtgt ttggcaagta accatatgtc cttctttccc acatgtcaga gaagtaccta

3721 tttttttcgg ttaaaaactg agacccttaa aaagccatgg tatcacagcc tctcagccct

3781 aaaaagcaaa gaccctccac aatgttattg tgattttatt tatgaaaaac ttagaagcga

3841 gatcatctga agtatgttca tgggaacaga actaaaagca gatccatgaa aaccatacct

3901 acagtcttaa gaacgttaaa tgctgtgtga aaataataga cctttcngaa gccctatcat

3961 ttctcccaga tcaccattta ggaaattatc tgatcaatgt catgattgat tcaaaattct

4021 agctaagcca ttttttggtc gtaacattga acaagtcagt ttacctctat gttcctgagt

4081 tttcacctgg aaaggaaggg taacagtcct tgctaccatg tgacgtccaa tggagtgaag

4141 gcagtagagt gtgtgatggt gcttcacagg actataggta ctacactgtg gtcttgccca
```

## Figure 21C cont'd

```
4201 taaaacccct ggggaactca tatagatcca gaggaaactg gctgcaggcg cgagcgatgg
4261 gtgaaaagag tttagcagca agttcgctcc caaaaaattc ctcccccaac actgttacta
4321 aactgtgtca cttcataatc aatgagggaa tgggtggatt gagatggttc cttgtcttaa
4381 agtgacctga cacactcagt ttgggggaaa aactttttat gaacatcaaa ttattctcta
4441 gatacagcca gatttactga cttgccatgt gtaggtcata gagctaggaa tgaaatatgc
4501 gcaacataaa ataataatca ataatcccat atcattatgg tacttgttat ttatattttc
4561 ctgtttcaac cttttatcat ccctgcaagg tagaacattc acactgatat tctcttacct
4621 atgctaccca aagacatcag ccctaattgt attttggaag atagctgact ggggctgatt
4681 gcagcctatg tcagcaggaa tagatgttgt tactgttgtt gcttctgctt tttttatttc
4741 catttatttg atagtacaga tctagagggt tctatctgaa ccttcccaac ctatacttca
4801 taataccatc ccactaaagt gtgatacaag aaacttcttc actctcttcc ctctacctat
4861 ttatgaaggc agataataaa ctggataata tttatcttca cttattcaac aaacatttat
4921 tgagtgccta ctaggatggt ggcagtggca gtgaaggaaa tgcaaggata caagatatag
4981 aatcaagggt tactcttaga atttttgctt tataaaacag atggatggtg aatgagatag
5041 ggaagactga gaaaacaaca ggatagagac atgattttat tttatagtga caaagaggct
5101 aaaaagaact gagagaactt cagtatattt agttgtagtt gctttgtgag tcagggcagt
5161 tgcatttgga attccctccc agattatgtt ttccaaaggg aaatcaaacc caattaataa
5221 atctgtgtct ccatttcagg tcaaaggaaa aatgataatg aattcattga gcctctttgc
5281 tgccatttct ggaatgattc tttcaatcat ggacatactt aatattaaaa tttcccattt
5341 tttaaaaatg gagagtctga attttattag agctcacaca ccatatatta acatatacaa
5401 ctgtgaacca gctaatccct ctgagaaaaa ctccccatct acccaatact gttacagcat
5461 acaatctctg ttcttggtaa gtgttcttgg taagtgtgag attggatttc tctccaggga
5521 ggaaggatga cttgtttatt atgagcatga actctgaatt ccagaccacc tgtgtttgtc
5581 tgcttcaact gattattcat accttacttt ctatcagcaa tacacattaa ccatctgttg
5641 tgtgccaaaa gttgtgttaa gagttagggt tataaagatg ctgtctcctg tactagcagt
5701 tctcacagct attcattact tgtctaaaga attgatctct taatcgttca attatagtca
5761 acaataactt actgaacacc aacaatgttc tttgtgccat tattacattt tcaccttcat
5821 tcttctgttg ttttttcaggg cattttgtca gtgatgctga tctttgcctt cttccaggaa
5881 cttgtaatag ctggcatcgt tgagaatgaa tggaaaagaa cgtgctccag acccaaatct
5941 gtaagtagta gcctccagca ccgtggtcaa tgtctgctgc ccttgaagat ttattcagac
6001 ttgagtttta ataaatgact tgataaggat ataagcacct gcaaaaaaat tttggcattt
6061 aaaggcatat aataaatgac ataagtagca taaaaaccag gaggtatttg ataaatgttt
6121 gtggagattg ttgacaaagg tgtcagttgt aaaagtaaag aatggtttgt ttaattttct
6181 gttttagaac atagttctcc tgtcagcaga agaaaaaaaa gaacagacta ttgaaataaa
6241 agaagaagtg gttgggctaa ctgaaacatc ttcccaacca aagaatgaag aagacattga
```

## Figure 21C cont'd

6301 aattattcca atccaagaag aggaagaaga agaaacagag acgaactttc cagaacctcc
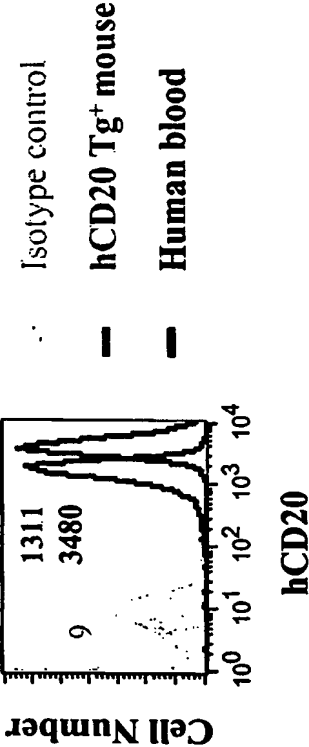
6361 ccaagatcag gaatcctcac caatagaaaa tgacagctct ccttaa

# FIGURE 21D

## Mouse CD20

```
   1 gaattccttt tttttttttt tttttaaaga tttatttatt attatatgta agtacactgt
  61 agctatcttc aagtacttga gatagaagag gccaactgat ctcagctgtg agtggctaat
 121 ttggccctta agccttggag ccttggagcc ttggagaccc aggcgtttga aaactcaatg
 181 agtggacctt tcccagcaga gcctacaaaa ggtcccctcg ccatgcaacc tgctccaaaa
 241 gtgaacctca aaaggacatc ttcactggtg ggccccacac aaagcttctt catgagggaa
 301 tcaaaggctt tgggggctgt ccaaatcatg aatggcctct tccatattac cctggggggga
 361 ctgctgatga tccccacagg ggtcttcgca cccatctgtt tgagtgtatg gtaccctctc
 421 tggggaggca ttatgtacat tatttcagga tcactcctgg cagctgcagc agaaaaaacc
 481 tccaggaaga gtttggtcaa agcaaaagtg ataatgagct ctctaagcct ctttgctgcc
 541 atttctggaa taattctttc aatcatggac atacttaaca tgacactttc tcattttta
 601 aaaatgagaa gactggagct tattcaaact tccaagccgt atgttgatat ctacgactgt
 661 gaaccatcta attcctcaga gaaaaactcc ccatctacac agtactgtaa cagcattcag
 721 tctgtgttct tgggcattct gtcggcgatg ctgatctctg ccttcttcca gaaacttgtg
 781 acagctggta ttgtggagaa tgagtggaaa agaatgtgta ccagatccaa atctaatgtg
 841 gttctgctgt cagctggaga aaaaaatgag cagacgatta aaatgaaaga agaaatcatt
 901 gagctaagtg gagtatcttc ccaaccaaag aatgaagagg aaattgaaat tattccagtg
 961 caggaggaag aagaagaaga agcagaaata aattttccag cacctcccca agagcaggaa
1021 tccttgccag tggaaaatga gatcgctcct taaactcttt tcttttctaa gcattattgt
1081 ttagagagct tccaagacac atagttaccc tcatctcttg tggccttcca caatctattc
1141 tccatatttt cacagcttaa ctttgcatag agaagccaca tctagctctc cttcacattt
1201 gaagaatgca gtgattataa aagattgtct tttgccttgc ttagggagtc ttacactggc
1261 agaaacgctg aagaatccaa ttctcattca cctttttcctt ggatgtgtgt ctcagtagtg
1321 gtaatggttt ttccgcattt cctccatcag cagttacagc agaaggagtc agagagttca
1381 gggaattc
```

Figure 22

# Human CD20 expression in peripheral blood



Isotype control

hCD20 Tg+ mouse

Human blood

*: gated on B cells